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# Audiometric evaluation short and medium term in cochlear implants

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**ABSTRACT**

**Objective.** Our purpose is report the results of cochlear implant program in this Institute, since our first surgery from November 2007, until December 2012. **Material and methods.** A cross-sectional study, observational, descriptive, analyzing the information about thresholds before and after implantation, using patients files (diagnosis, onset of hearing loss, brainstem auditory evoked potential (BAEP), computed tomography (CT), magnetic resonance imaging (MRI), implanted ear, brand and model of cochlear implants (CI) and audiometric studies before and after the CI. **Results.** We report the evolution of 68 patients, age ranged 1 year 8 months to 39 years 3 months old. 94% patients (n = 64) had pre-lingual hearing loss being hereditary non-syndromic hearing loss the most common etiology (29.4%). 100% patients had auditory brainstem responses showing bilateral profound hearing loss, in the 77.9% type A tympanograms were obtained (Jerger's classification), and 100% had absence of stapedial reflexes and otoacoustic emissions with low reproducibility. CT reported as normal in 85.2% of patients, the findings: 5.8% had chronic mastoiditis changes, other findings reported in 1.4% of patients were: digastric right facial nerve, facial nerve canal dehiscence, enlarged vestibular aqueduct, occupation and poor pneumatization of mastoid air cells, lateral semicircular canals agenesis, incomplete partition of the cochlea with wide vestibular and vestibular aqueduct dilatation. Most frequent MR findings of skull with cerebellopontine angle approach were vascular loops of internal auditory canals unilaterally. In 10.2%, 55.8% of patients (n = 38) were implanted in the right ear, 56 (82.3%) with a CI from Advanced Bionics, HiRes 90K model, the remaining with Cochlear, Freedom and Nucleus 5 models. Developments in CI results by audiometric tests: prior to placement was 106.2 dB averages at frequencies assessed, one month later 62.4 dB, at 6 months 44 dB, and with satisfactory threshold 32.9 dB. 55.8% of patients (n = 38) with P + HiRes Fidelity 120 strategy, the remaining with Hires S + Fidelity 120, Hires S and ACE RE. **Discussion.** Audiology service proposed to place the CI in the worst ear by threshold in audiometric tests, the oto-

***Evaluación audiométrica a corto y mediano plazo en implantes cocleares***

***RESUMEN***

***Objetivo.*** *La finalidad del presente estudio es reportar los resultados audiométricos obtenidos en el Servicio de Audiología, en el Instituto Nacional de Rehabilitación, con la colocación del implante coclear de noviembre 2007, en que se realizó el primer implante en este instituto, hasta diciembre 2012.* ***Material y métodos.*** *Estudio transversal, observacional, descriptivo, analizando los umbrales de audición, pre y postimplante coclear, mediante revisión de expedientes (diagnóstico, edad de instauración de la hipoacusia, potenciales provocados auditivos de tallo cerebral (PPATC), tomografía computarizada (TC), resonancia magnética (RM), lateralidad del oído implantado, marca y modelo de los implantes cocleares (IC), estudios audiométricos previos y posteriores al IC.* ***Resultados.*** *Se reporta la evolución de 68 pacientes, teniendo un rango de edad de un año-ocho meses a 39 años-tres meses de edad. El 94% de los pacientes (n = 64) presentó hipoacusia pre-lingual, siendo la hipoacusia hereditaria no sindrómica la etiología más frecuente (29.4%). El 100% de los pacientes presentó hipoacusia profunda bilateral en PPATC, en 77.9% se obtuvieron timpanogramas tipo A de la clasificación de Jerger, 100% con ausencia de reflejos estapediales y emisiones otoacústicas con inadecuada reproductibilidad global y por frecuencia. La TC de oídos se reportó como normal en 85.2% de los pacientes, los hallazgos fueron: 5.8% presentó cambios por mastoiditis crónica; otros hallazgos reportados en 1.4% de los pacientes fueron: bifurcación del nervio facial, dehiscencia del canal del nervio facial derecho, dilatación del acueducto vestibular, ocupación e hiponeumatización de celdillas mastoideas, agenesia de canales semicirculares laterales, partición incompleta de cóclea con dilatación vestibular y del acueducto vestibular. Los hallazgos mas frecuentes por RM de cráneo con enfoque a ángulo pontocerebeloso fueron las asas de conductos auditivos internos de forma unilateral en 10.2%. El 55.8% de los pacientes (n = 38) fueron implantados del oído derecho, 56*

laryngology service proposed the best ear from anatomical point view. Implanted in the INR more Advanced Bionics CI faq frequently due to the donation by the insurance for a new generation. Hearing thresholds using CI have improved since activation.

**Key words.** Hearing loss. Deafness. Cochlear implant. Auditive gain. Audiology.

*(82.3%) con un IC marca Advanced Bionics modelo HiRes 90 K, los restantes con IC marca Cochlear, modelos Freedom y Nucleus 5. La evolución de la respuesta del IC en pruebas audiométricas: previo a la colocación del mismo fue de 106.2 dB por promedio de los umbrales estimados en las frecuencias evaluadas, un mes posterior: 62.4 dB, a los seis meses: 44 dB, con umbral satisfactorio: 32.9 dB. El 55.8% de los pacientes (n = 38) con estrategia Hires P + Fidelity 120, otras estrategias utilizadas fueron Hires S + Fidelity 120, Hires S y ACE-RE.* ***Discusión.*** *El oído elegido por médicos audiólogos para colocar el IC fue aquel cuyo umbral presentara mayor deterioro, en tanto que el Servicio de Otorrinolaringología tomó en cuenta los hallazgos por imagen para elegir el mejor oído desde el punto de vista anatómico. En el INR se implantó con mayor frecuencia IC marca Advanced Bionics, debido a la donación por parte del seguro para una nueva generación. Los umbrales auditivos con el uso de IC presentaron mejoría desde la activación.*

***Palabras clave.*** *Hipoacusia. Sordera. Implante coclear. Ganancia auditiva. Audiología.*

## INTRODUCTION

Hearing loss is the most common birth defect, with a prevalence of 1-3 per 1,000 births. According to WHO, in México 10 million people have some form or degree of hearing impairment, 200,000-400,000 with bilateral profound hearing loss, 3 of each 1,000 newborns have some kind of disability by hearing loss. A child, who does not hear, does not develop oral language and it will be virtually impossible to learn to read and write.[1]

The classification of the degree of hearing loss according to WHO is:

- Normal hearing: hearing threshold from 0 to 25 dB.
- Mild hearing loss: threshold of 26-40 dB.
- Moderate hearing loss: threshold of 41-60 dB.
- Severe hearing loss: threshold of 61-80 dB.
- Profound hearing loss: threshold of 81 dB or greater.

Accordingly the location of the lesion there are two variety of hearing losses, conductive and sensorineural, the first corresponding to those patients with lesion of the mechanical part of the ear (outer ear and/or medium processes), sensorineural hearing loss are those patients with lesions to the organ of Corti or pathways or higher auditory centres.[2]

The plan for the treatment of patients, should be based in develops on the deaf child the same cognitive strategies developed by the listener and not only in the development of a media in which the subject is competent. Treatment should be multidisciplinary and individualized according to the degree and cause of hearing loss, age of the patient, language development, family, etc. Most children diagnosed with hearing loss benefit from amplification through the binaural hearing aids whenever possible. The development of oral language and/or sign language should be adequate for the child's age and cognitive skills, acquiring phonological skills (for spoken language), visual/spatial/motor (for language sign), morphological, semantic and pragmatic. The specific goals of early intervention aim to facilitate the development of language skills enhance understanding of family strengths and needs of the child and promote the ability of the family to defend his son.[3]

The cochlear implant is a device surgically placed in individuals with severe to profound sensorineural hearing loss who do not benefit from the use of hearing aids, which electrically stimulates the auditory nerve, and thus sends sound information to the central nervous system through the auditory patway.[4]

It consists of external and internal components. External components are: microphones, sound processor, batteries and a transmitter that sends information (electrical coding). The inner part is made up of the receiver stimulator that is placed under the skin, the electrodes guide and the electrodes are inserted into the cochlea.[5,6]

The criteria for designating a candidate for cochlear implant patients have been modified over time, and thus also the therapeutic possibilities in patients who have already been benefited with the use of this device; these possibilities ranging from the use of a binaural cochlear implant, until the bimodal stimulation that involves the use of a cochlear

implant and contralateral hearing aid.[7] Cochlear implant models differ in design and presentation as in strategy type, stimulation mode, and stimulation rate, and telemetry, number of active electrodes per cycle, electrode design, safety features, and etc.[8]

From 2 to 4 weeks after surgery cochlear implant placement it is activated, that activation consists in the implementation of a map, by adjusting the speech processor so that patients can detect environmental sounds and speech. Each patient will merit of an individual and untransferable adjustment of your processor. These programming will be made gradually, and periodically, based on both behavioral responses and with the help of other objective measures as are the image of neural response or neural response telemetry, acoustic reflex triggered electrically or by electrically evoked potentials.

Since the point of audiometric view there are different methods to assess the users of cochlear implant patients at short and long term.[9-11] However at short-term and in users primarily in childhood are useful psychophysical procedures based on observation, as is the study of Dasika, *et al.,* where it reported as a useful method in implanted children between 9 and 20 months of age.[12]

In the Instituto Nacional de Rehabilitación (INR) there is a commitment to the rehabilitation and empowerment of persons with hearing disabilities through the establishment of the cochlear implant program. The cochlear implant committee consists of Audiology and Otolaryngology services, Language Therapy, Psychology and Social Work. The staff of these services evaluates these patients and during this assessment, audiology service carry out audiological and electrophysiological studies (audiometry, tympanometry, stapedial reflexes, otoacoustic emissions, brainstem auditory evoked potentials) and imaging studies requested like computed tomography and magnetic resonance ears.

The INR not only take into account the audiological criteria for the selection of candidates, but also other disciplines:

- *Audiological criteria in adults and children.* Bilateral severe to profound sensorineural hearing loss; with gain of hearing aids high power in the best conditions of use and programming, with mean threshold (reliable) at frequencies of spoken language 60 dBHL or greater,[13] absence of wave V at 80 dB and transient otoacoustic emissions with inadequate overall reproducibility and by frequency.
  a) In adult patients. 18 to 60 years, with evolution of hearing loss less than 10 years with constant stimulation through the use of hearing aids.
  b) In pediatric patients. 12 to 36 months in pre linguistic patients, 3-7 years in patients peri- and post-linguistic, higher than 7 years.
- *Otolaryngology criteria.* Permeable cochlea, whole auditory nerve without middle ear pathology.
- *Criteria for language therapy.* At least 6 months of therapy with the use of hearing aids properly adapted with speech perception test less than 30%.
- *Psychological criteria.* Realistic expectations and motivation of the family and the patient, family support, and executive intellectual ability or development coefficient (depending on age) of 90 or more, with no history psychiatric or behavioral disorders.
- *Social work criteria.* Considering economic situation, family support, conditions and service of the home and the school.

In this institution the patient is regularly monitored according to their individual needs, patients are regularly assessed by the same multidisciplinary team. The results of the programming and the development of language to the patient are done by the Audiologist. Medical Audiologist work is done in conjunction with Language Therapy who will also guide the parents in process of developing language skills in the patient. Psychological services and social work provide the patient and family support networks that each patient requires. Further according to the needs of each case is given by monitoring other specialists.

Since November 2007, that was placed the 1st cochlear implant in the RNI, to December 2012, 69 cochlear implants were performed, so that the objective of this study is to report the results in the short term the type and programming method and audiometric gain.

## MATERIAL AND METHODS

In order to analyze the results of patients with cochlear implant in the INR according on the hearing gain and to report the characteristics of the patient population, a cross-sectional, observational and descriptive study was performed.

From November 2007 to December 2012, 69 patients underwent surgery for placement of cochlear

implant, in this work the immediate results of 68 patients were analyzed as one patient left his follow up after activation of the implant. The following cases with complications are included in the 68 patients analyzed in this work; however by the time it occurred merited to be excluded:

- *First case.* Patient that required explantation and reimplantation in the same ear due to implant placement to the vestibule.
- *Second case.* Patient with failure implant Nucleus 5 is reimplanted in the same ear and enters the present work after this reimplanted.
- *Third case.* Patient with recurrent retroauricular abscess, which is explanted at 2 years of implantation, the patient's family rejects reimplantation.

Electronic records of patients included in this study were reviewed, collecting and analyzing the following information:

- Etiology of hearing loss, which was established, pre or post-lingual, results in studies of auditory brainstem evoked potentials, findings in studies of CT and MRI, ear the cochlear implant, trademark and model of implants.
- Audiometry studies prior to placement of the cochlear implant, one month and 6 months after implant placement were analyzed. The audiometric study was conducted according to the age of patients and the degree of cooperation (audiometry observation of behavior, conditioning audiometry with toys and pure-tone audiometry), free field with FM tones.[12]
- In addition the first audiometric study was taken into account with thresholds in the area of language or area Wegel's. As well as these thresholds are reached.

## RESULTS

Evolution of 68 patients, were reported, aged 1 year 8 months to 39 years 3 months.

Using the following information:

- Audiological studies pre cochlear implant: in all patients.
- Audiological studies after one month of cochlear implant placement (± 2 months) in 51 patients.
- Audiological studies after 6 months of cochlear implant placement (± 2 months) in 57 patients.
- Audiology studies with satisfactory threshold: 57 patients, considering satisfactory patients with thresholds between normal hearing and surface hearing loss.

In relation to the time of onset of hearing loss in only 4 (5.8%) patients were with post-language hearing loss and 64 (94%) of the patients were pre-language hearing loss. The most common causes of hearing loss in our patient group were hereditary non-syndromic in 20 (29.4%) patients, adverse birth factors in 15 (22%), and in 26 (38.2%) cases failed to identify a possible cause of hearing loss, other causes of hearing loss were: congenital rubella, genetic syndromes (Norrie's syndrom), infectious, post-ototoxic, autoimmune disease and meningitis (Table 1).

### Audiological studies

One hundred percent of patients had bilateral profound hearing loss, and to evaluate the gain obtained with hearing aid did not reach the Wegel's area.

Subjective audiological studies were complemented by objectives audiological research.

Brainstem auditory evoked potentials: all patients had bilateral profound hearing loss by high frequencies, from 100 ears evaluated only 1 (1.47%) was found threshold to 80 dB in the right ear, the other patients had thresholds ≥ 90 dB in both ears (Table 2).

Table 1. Etiology of deafness in implanted patients in the Instituto Nacional de Rehabilitación.

| Etiology | Patients, n (%) |
|---|---|
| Hereditary non-syndromic | 20 (29.4) |
| Not determined | 26 (38.2) |
| Adversely birth factors | 15 (22) |
| Post-ototoxic | 2 (2.9) |
| Congenital rubella | 1 (1.4) |
| Norrie's syndrom | 1 (1.4) |
| Autoinmune desease | 1 (1.4) |
| Meningitis | 1 (1.4) |
| Infectious | 1 (1.4) |

**Table 2.** Brainstem auditory evoked potentials thresholds.

| Tresholds | Right ear | Left ear |
|---|---|---|
| Without response to 100 dB | 62 (91.1%) | 63 (92.6%) |
| 100 dB | 4 (5.8%) | 4 (5.8%) |
| 90 dB | 1 (1.4%) | 1 (1.4%) |
| 80 dB | 1 (1.4%) | |

The steady stead auditory potentials test was not performed in all patients, since in this institute the necessary equipment was purchased until 2012.

- *Tympanometry*. Patients during their evaluation showed middle ear pathology were treated closely by Otolaryngology Service and therefore at the time of surgery the majority of patients, 53 (77.9%) had tympanograms type A, according to the Jerger classification (with pressures, morphology, gradient and compliances in normal range), however other type of tympanogram before surgery were As type in 12 (17.6%) patients and C type in 3 (4.4%) patients.
- *Stapedial reflexes*. In all patients the stapedial reflexes were found absent both ipsilateral and contralateral to 110 dB in both ears.

Transient otoacoustic emissions: all patients had inadequate reproducibility both overall and frequency in both ears (as appropriate considering above 70% reproducibility).[14]

## Imaging studies

In 100% of pre-surgery patients TC of ears was performed, reporting as normal in 58 (85.2%) patients, 4 (5.8%) patients had changes by chronic otomastoiditis, the following changes were reported with frequency of 1 (1.4%) patient by each alteration: branch of the facial nerve, canal dehiscence of the right facial nerve, enlarged vestibular aqueduct, lack of pneumatization of mastoid cells, bilateral agenesis of bilateral lateral semicircular canal, incomplete partition of cochlea with vestibular dilatation and dilatation of vestubular canal (Table 3).

- *MRI scan*. Of the 68 implanted patients were analyzed, 53 were performed MRI study approach to ear with cerebellopontine angle. In 32 (47%) patients the study was normal, the most common findings were: 7 (10.2%) with vascular loop in internal auditory canals unilaterally, in table 4 other findings are mentioned.

The MRI study was not done in all patients, as initially was performed only in those patients with al-

Table 3. Findings on computed tomography test.

| Findings | Patients (%) |
|---|---|
| No alterations | 58 (85.2) |
| Chronic otomastoiditis changes | 4 (5.8) |
| Branch of facial nerve in right ear | 1 (1.4) |
| Canal dehiscence of the right facial nerve | 1 (1.4) |
| Enlarged of bilateral vestibular canal | 1 (1.4) |
| Mastoid encroachment in left ear | 1 (1.4) |
| Hipopneumatization of mastoid cells | 1 (1.4) |
| Bilateral agenesis of semicircular canal | 1 (1.4) |

Table 4. Findings on MRI studies of ears.

| Findings | Patients (%) |
|---|---|
| No alterations | 32 (47) |
| Not performed | 15 (22) |
| Otological findings | |
| Vascular loop in left internal auditory canal | 4 (5.8) |
| Vascular loop in right internal auditory canal | 3 (4.4) |
| Vascular loop bilateral | 2 (2.9) |
| Right cochlear hypoplasia | 1 (1.4) |
| Discontinuity of left semicircular canal | 1 (1.4) |
| Vestibular dilatation from duct and endolymphatic sac | 1 (1.4) |
| Other intracranial findings | |
| Temporal arachnoid cyst | 4 (5.8) |
| Cortical hypoplasia | 2 (2.9) |
| Periventricular leukomalacia | 2 (2.9) |
| Periventricular leukomalacia associated with hypotrophy of the corpus callosum and secondary ventriculomegaly | 1 (1.4) |
| Cisterna magna as an anatomical variant | 1 (1.4) |
| Corticosubcorital atrophy exvacuo with hydrocephalus, leukomalacia supratentorial diffuse | 1 (1.4) |
| Leukomalacia punctate periventricular parieto occipital | 1 (1.4) |

Table 5. Cochlear implants in patients of the Instituto Nacional de Rehabilitación.

| Implant | Patients, n (%) |
|---|---|
| Advanced bionics | 56 (82.3) |
| HIRES 90 K | |
| Cochlear | 12 (17.6) |
| Freedom | 5 (7.3) |
| Nucleus 5 | 7 (10.2) |

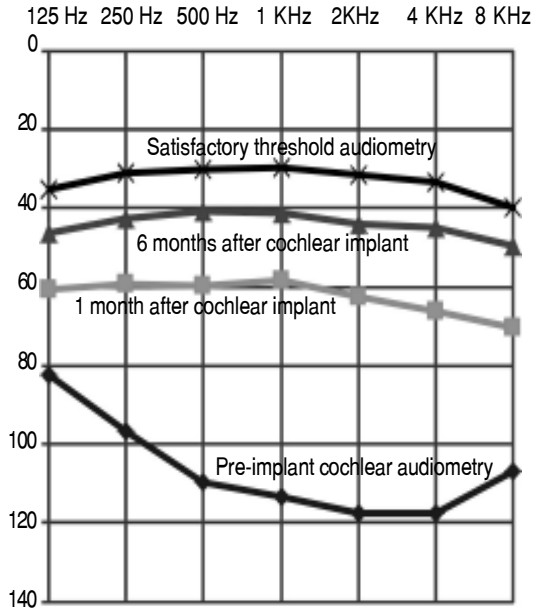


*Figure 1. Average obtained from estimates audiometric thresholds pre cochlear implant at one month and 6 months after insertion of the cochlear implant and audiometry was considerate with satisfactory threshold.*

terations in the study of computed tomography or had a specific indication, however from October 2009 was integrated as a compulsory study in the evaluation protocol of patients under study.

### Cochlear implant

In 38 (55.8%) patients the implanted ear was right, and 30 (44.1%) the left. 56 (82.3%) have the HiRes 90K implant trademark Advanced Bionics, the remaining patients using implants Cochlear, Freedom and Nucleus 5 models (Table 5).

### Gain with the use of the cochlear implant

In assessing audiometry and get the average of the estimates thresholds on assessed frequencies, prior to placement of the cochlear implant (ear to implant) was 106.2 dB, one month later post-implant placement the average was 62.4 dB, at 6 months after implantation was 44.0 dB and when analyzing the audiometry with satisfactory threshold the average was 32.9 dB.

Table 6. Strategies used in programming with that obtained an estimated satisfactory audiological threshold.

| Strategie | Patients, n (%) |
|---|---|
| Advanced bionics | |
| HI-RES P/Fidelity 120 | 38 (55.8) |
| HI-RES S/Fidelity 120 | 5 (7.3) |
| HI-RES S | 1 (1.4) |
| Cochlear | 12 (17.6) |
| ACE-RE | |
| Left their follow | 2 (2.9) |
| There are not information | 1 (1.4) |
| Not even come to satisfactory threshold | 9 (13.2) |

The figure 1 show the average gain in patients with cochlear implant used per month, at 6 months and by when the audiometric thresholds described were considerate satisfactory, evaluating the 7 frequencies from audiogram.

It reached a satisfactory threshold on average at 14 months after insertion of the cochlear implant (standard deviation 7.59), having a variance between 4 and 36 months.

The most commonly used strategy was Hires P with Fidelity 120 Brand Advanced Bionics, being 38 (55.8%) patients who used this strategy. In patients with cochlear implants Cochlear brand the strategy used in all patients was ACE-RE (Table 6).

## DISCUSSION

In Latin America the first single-channel implant was placed in 1979 in Buenos Aires, Argentina, and a year later the first multichannel implants in Argentina and in México were placed by Dr. Ernesto Deutch. The INR-Cochlear Implant Committee is a relatively young group, with the placement of the first cochlear implant in November 2007.

In audiological studies all patients had profound hearing loss in the speech frequencies, with insufficient gain by using hearing aids with normal tympanometry studies at the time of surgery, in the auditory brainstem evoked potential responses corresponded to hearing loss severe or profound, and less than 70% reproducibility in the study of tran-

sient otoacoustic emissions. Based on audiometric studies, it was chosen for placement of cochlear implant the ear with more deterioration, so that after implantation the patients continue using hearing aid in the contralateral ear and which provides bimodal stimulation. However the Department of Otolaryngology, getting studies CT and MRI, took into account the anatomical alterations found in patients, thus choosing the ear with less morphological alterations, predominantly heard chosen by the Service of Audiology.

For the analysis of the results, it was not possible to obtain full audiological studies, since not counted in some cases to the report in the system, and in other cases had not reached within 6 months or closure study had not reached the desired threshold.

As seen in figure 1, and according to expected with the use of cochlear implant users patients using cochlear implants are quickly benefited from the time of activation from the point of view audiometric. However the range of time in reach a satisfactory hearing threshold is large for various reasons; in foreign patients programming are more spaced, in other cases there are patients who leave your follow up for long periods of time, and of the 68 patients analyzed in this study, in 11 were not analyzed this information because 2 patients discontinued their monitoring before obtained thresholds at month or 6 months, and 9 patients were surgery 6 months before the end of this work and then had not yet achieved a satisfactory threshold.

The strategy most commonly used in our patient was the Hi Res P with Fidelity 120; however we cannot perform a statistical analysis because most patients have devices branded Advanced Bionics (Table 6).

This study has the limitation of only evaluating audiometric evolution of implanted patients, however there is a commitment by the Institute to assess and report the main purpose of this form of treatment, "language development", looking in our patients develop the same cognitive strategies developed by the listener, through the development of a communication media in which the subject is competent, the acquisition of communication skills, social skills, emotional well-being and self-esteem.

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