ORIGINAL ARTICLE

Otoacoustic Emissions as Cochlear Function Analyser in Children With Language Disorders∗

Silvia A. Aguilera-Tello, a Ileana Gutiérrez-Farfán, a Laura E. Chamlati-Aguirre, a Efrén Alatorre-Miguel, b Alfredo Durand-Rivera b,∗

a División de Audiología y Otoneurología, Instituto Nacional de Rehabilitación, Mexico City, Mexico
b Servicio de Neurorrehabilitación, Laboratorio de Neuroprotección, Instituto Nacional de Rehabilitación, Mexico City, Mexico

Received 27 February 2014; accepted 25 May 2014

KEYWORDS
Language;
Transient otoacoustic emissions;
Audiometry;
Language disorder;
Language therapy

Abstract
Introduction and objectives: Speech perception that takes place in the cochlea is involved in the process of language. The objective was to describe the findings in transient otoacoustic emissions in children with language problems before and after 6 months of speech therapy.
Methods: There were 17 children with language problems between 3 and 6 years of age diagnosed with anarthric language delay (expressive and mixed language disorder). They underwent medical history, otoscopy, intelligence level testing, initial language test, tympanometry of 226 Hz, audiometry and transient otoacoustic emission test.
Results: We evaluated the 17 patients again after 6 months of attending speech therapy. The percentage of overall reproducibility of transient otoacoustic emissions in both ears was adequate to perform frequency analysis. We found a statistically significant difference (P≤.01) in the frequency of 1 kHz reproducibility when comparing results before and after therapy in the right ear. There was a significant difference (P≤.05) when comparing the results of audiometry at frequencies of 0.5, 1.5, 2, 4 and 8 kHz in the right ear and a highly significant difference (P≤.001) in the frequency of 3 kHz in the left ear.
Conclusions: The analysis of sound through the cochlea is involved in the process of language acquisition. A poor processing of speech sounds in the peripheral system could result in poor processing at the central level. Consequently, it is important to consider our results when making a diagnosis and carrying out rehabilitation treatment in children with language disorders.
© 2014 Elsevier España, S.L.U. and Sociedad Española de Otorrinolaringología y Patología Cervico-Facial. All rights reserved.


∗ Corresponding author.
E-mail address: alfredo.durand@gmail.com (A. Durand-Rivera).
Introduction

It is generally considered that an alteration in language function reflects a brain abnormality and, more specifically, of the dominant hemisphere.1-3

Neurolinguistics assumes that the production of the acoustic signal of speech represents the result of articularatory maneuvers performed by the speaker, which are the product of a series of signals transmitted by the central nervous system.4-6

Ardila, modifying the model of Fant,7 proposed that acoustic signals reaching the cochlea undergo a tonotopic analysis. Subsequently, this afferent information undergoes processing, from the brainstem to the cortex, in order to produce language recognition.8,9

Adequate temporal processing is one of the most important factors for language intelligibility. Slower rates of modulated amplitude, from 4 to 20Hz, are important in segmenting language into smaller units.10

Otoacoustic emissions are considered to be the product of cochlear amplification, which represents a phenomenon whereby the cochlea is responsible of selecting frequencies with great sensitivity and a wide dynamic range. The discovery of the motility of outer hair cells by Brownell in 198311-15 provided a physical substrate for active processes in the cochlea, since the measurement of the individual force generated by outer hair cells indicates that the activation of a sufficiently large number of cells would be capable of changing a portion of the mechanical response of the cochlea.13,16 This phenomenon could be regarded as a cochlear tuner.

Taking the foregoing into account, we believe that information analysis by the cochlea has a greater involvement in the process of language acquisition than currently thought. Since otoacoustic emissions provide a means of studying cochlear function, they could be used to verify whether the cochlea is somehow involved in language problems and could represent an objective marker used before and after language therapy to evaluate evolution.

Methods

We conducted a cross-sectional and descriptive study of 25 patients, aged between 3 and 6 years, with a diagnosis of anarthric language delay17 (expressive and mixed language disorder), and a normal intelligence quotient as corroborated by the WPPSI (Wechsler Preschool and Primary Scale of Intelligence) and Hickey-Nebraska tools. Subjects were audiologically evaluated before and 6 months after rehabilitation treatment.

Once the protocol was approved by the Ethics and Research Committee of the National Rehabilitation Institute and we had obtained informed consent in writing from the parents or tutors of the children, we elaborated a medical history and proceeded to conduct the following studies:

Tympanometry at 226 Hz, conducted using a Madsen Zodiac 901 tympanometer in a soundproofed chamber on both ears to rule out middle ear pathology and verify the normalization of tympanometry curves (type A). This was a requirement before conducting tone audiometry and transient otoacoustic emissions (TOAE) testing.

Tone audiometry. We used a Madsen Orbiter 922 audiometer in a soundproofed chamber, to obtain the minimal detection of pure tones at the frequencies of 125, 250, 500, 1000, 1500, 2000, 3000, 4000 and 8000 Hz.

TOAE. We used an Otodynamics ILO-96 device in a soundproofed chamber, placing a pediatric probe first in the
Table 1  Transient Otoacoustic Emissions.

<table>
<thead>
<tr>
<th></th>
<th>Before the therapy</th>
<th>After 6 months of therapy</th>
<th>P</th>
<th>Before the therapy</th>
<th>After 6 months of therapy</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right ear (%)</td>
<td></td>
<td></td>
<td>Left ear (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>90.9</td>
<td>96.2</td>
<td>.1843</td>
<td>93.9</td>
<td>96.4</td>
<td>.4889</td>
</tr>
<tr>
<td>1.0 kHz</td>
<td>57.7</td>
<td>80.8</td>
<td>.0500</td>
<td>77.5</td>
<td>89.9</td>
<td>.1581</td>
</tr>
<tr>
<td>1.5 kHz</td>
<td>86.4</td>
<td>95.4</td>
<td>.0755</td>
<td>90.6</td>
<td>96.5</td>
<td>.2340</td>
</tr>
<tr>
<td>2.0 kHz</td>
<td>91.3</td>
<td>96.8</td>
<td>.2490</td>
<td>96.5</td>
<td>96.2</td>
<td>.9166</td>
</tr>
<tr>
<td>3.0 kHz</td>
<td>92.1</td>
<td>97.2</td>
<td>.2457</td>
<td>95.7</td>
<td>96.7</td>
<td>.7158</td>
</tr>
<tr>
<td>4.0 kHz</td>
<td>88.7</td>
<td>96.9</td>
<td>.1970</td>
<td>93.0</td>
<td>95.3</td>
<td>.5817</td>
</tr>
</tbody>
</table>

Mean percentage of reproducibility of transient otoacoustic emissions in both ears, before and after 6 months of language therapy. There is a statistically significant difference (P<.05) in the right ear, at the frequency of 1 kHz.

Results

We ruled out four of the initial 25 patients (one due to submucosal cleft palate and three due to middle ear problems that could not be resolved by medical treatment), thus leaving 21 patients. Of these, four dropped out after not attending language therapy sessions, leaving a final universe of 17 patients evaluated after 6 months of therapy. The mean age of the patients was 4.5 years, and there were 10 males and seven females. All subjects presented an intelligence quotient within normal parameters. The ITL was below the level of normality before the start of language therapy in all the children evaluated, but these results were not analyzed in depth, as this was not the aim of the investigation.

The overall percentage of reproducibility of TOAE in both ears was adequate for all patients before and after language therapy, thus confirming normal bilateral hearing.

The results of frequency analysis (1, 1.5, 2, 3 and 4 kHz) of reproducibility of TOAE in both ears before and after 6 months of undergoing language therapy are shown in Table 1.

We performed the Student t test for related samples, finding a statistically significant difference (P<.05) in the frequency of 1 kHz when comparing reproducibility before and after therapy in the right ear (Table 1 and Fig. 1).

Tone audiometry in all the evaluated frequencies (125, 250, 500, 1000, 1500, 2000, 3000, 4000 and 8000 Hz), identified responses below 20 dB, considered as normal bilateral hearing.

Table 2 shows the mean values of responses obtained by tone audiometry in each of the frequencies before and after language therapy.

We performed the Student t test for related samples, finding a significant difference (P<.05) when comparing the results of the audiometry at frequencies of 0.5, 1.5, 2, 3, 4 and 8 kHz in the right ear and a very significant difference (P=.05) in the frequencies of 2, 3, 4 and 8 kHz in the left ear (Table 2).

Discussion

Out of the total 25 patients evaluated, we found that 4% presented a submucosal cleft palate. This is a high percentage if we consider that the incidence in Mexico is of 3521 new
cases per year, which corresponds to 9.6 new cases per day. A prevalence of 139,000 Mexicans affected by some form of cleft lip or palate was reported in 2003. These figures indicate that this pathology is probably underdiagnosed in our country.

Among our patients, 12% presented some form of middle ear problem that did not remit after medical treatment and 16% dropped out of language therapy after not attending. This percentage is worrying, as it indicates desertion of rehabilitation treatment for language problems at our institute.

Regarding the evaluated population, 41% were females and 59% were males. These percentages are not surprising, as several studies have reported that language disorders are more common among males.

It was also expected that the overall reproducibility of TOAE would be over 70% in both ears, both before and 6 months after language therapy. In the case of our study, we observed a percentage over 90%, due to the fact that all patients presented normal bilateral hearing, so we could confirm that the middle ear did not suffer any alterations and the function of outer hair cells was normal. The literature contains reports estimating normal values for TOAE over 70% with reproducibility among individuals with normal hearing. We did not find any significant differences in the overall reproducibility in both ears when evaluating subjects before and after undergoing language therapy, but it is worth mentioning that the right ear presented an increase, from a mean value of 90.9% before the therapy to 96.15% after 6 months of therapy (Table 1 and Fig. 1).

An interesting part is the analysis of frequency reproducibility of TOAE. We found a statistically significant difference ($P \leq .01$) at a frequency of 1 kHz when comparing reproducibility before and after therapy in the right ear. This finding could be explained and support the theories reported in other studies. We know that hair cells are the real auditory receptors in the cochlea, specifically in the organ of Corti. This is particularly true of outer hair cells which, due to their morphological characteristics, are capable of modifying the mechanical response of the cochlea and influence inner hair cells, probably acting as a modulator of the cochlear response. Thus, in our patients with language disorders, the reproducibility in TOAE at 1 kHz is under the normal values, with a mean of 57.6%, and improving up to 80.7% after 6 months of language therapy (Table 1). From this we can infer that language disorders with a phonological etiology involve a malfunction of outer hair cells, which improve after specific therapy.

Moreover, we consider that the superior olivary complex fulfills an essential role in binaurality, being the first location of crossed information to reach the cochlear nuclei. This is the origin of the efferent fibers that constitute the medial olivo-cochlear bundle, creating synapses directly in the base of the outer hair cells. Therefore, we can assume that if TOAE evaluate the functionality of these cells, there is a malfunction at a cochlear level in one or more of the frequencies evaluated. In our study, this was 1 kHz, which is the mean frequency par excellence for correct intelligibility of spoken words. Another study found alterations in other TOAE frequencies, specifically 3, 4 and 5 kHz, when evaluating patients with language disorders. As a result of this malfunction, there is no adequate treatment of auditory information for the sounds of language. Moreover, it is well-known that the right ear is a crossed reflex of the olivo-cochlear bundle originating in the left hemisphere (the hemisphere specializing in language).

When analyzing the results of the audiometry we found a significant difference ($P \leq .05$) when we compared the results at middle and high frequencies in the right ear and at high frequencies in the left ear (Table 2).

It is important to highlight that there was also a statistically significant improvement in these frequencies studied in our sample of patients with language disorders, with the right ear also reflecting a greater improvement than the left, thus supporting our ideas.

## Conclusions

We can conclude that the peripheral analysis of auditory information conducted in the cochlea is involved in the process of language acquisition. Therefore, a wrong processing

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Tone Audiometry.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the therapy</td>
<td>After 6 months of therapy</td>
</tr>
<tr>
<td><strong>Right ear (dB)</strong></td>
<td></td>
</tr>
<tr>
<td>125 Hz</td>
<td>18.5</td>
</tr>
<tr>
<td>250 Hz</td>
<td>15.9</td>
</tr>
<tr>
<td>500 Hz</td>
<td>13.8</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>12.1</td>
</tr>
<tr>
<td>1500 Hz</td>
<td>12.9</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>12.1</td>
</tr>
<tr>
<td>3000 Hz</td>
<td>11.2</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>9.4</td>
</tr>
<tr>
<td>8000 Hz</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*Mean values in dB of the results of the tone audiometry in both ears before and after 6 months of therapy. There is a statistically significant difference ($P \leq .05$) in the right ear at the frequencies of 0.5, 1.5, 2, 3, 4 and 8 kHz and in the left ear at the frequencies of 2, 3, 4 and 8 kHz (figures marked in bold).*
Otoacoustic Emissions as Cochlear Function Analyser in Children With Language Disorders

of language sounds by the peripheral system, as proven by TOAE and tone audiometry, could result in auditory information arriving distorted at the level of the auditory cortex. This makes it very important to take the results into account when establishing a diagnosis and rehabilitation treatment through language therapy in children with phonological language disorders. These results suggest we should use otoacoustic emissions and audiometry as an objective marker before and after language therapy to evaluate patient evolution. It is important to continue investigating in this field in order to decipher the role of peripheral auditory processing in language, as well as to establish the usefulness of otoacoustic emissions and audiometry for the evaluation of patients with language disorders.

Conflict of Interests

The authors have no conflict of interests to declare.

References