Language development in Mexican children who use cochlear implants and their relationship with auditory and social factors

Cochlear implants in Mexican children

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***Abstract*—**To evaluate the auditory and socio-environmental factors involved in the language development of Mexican children who use cochlear implants. Cross-sectional and descriptive study. 13 children with cochlear implants were analyzed, the MacArthur-Bates Communicative Skills Inventory (CDI) was used to measure their grammatical and functional products as well as a parental questionnaire to collect information on the auditory and socio-environmental factors of the participants. The central trend statistics for each of the variables were obtained, as well as the Spearman correlation coefficient for the relationship between auditory and socio-environmental factors. The mean auditory age was 43.9 months and they received on average 36.6 months of therapy (95% CI: 20.4-52.8). The mean time of use of the hearing aid was 11.3 months with an average use of 12.9 hours per day. The largest number of words they were able to produce were nouns (112.62 ± 77; CI 95%: 65.6-159.6), followed by verbs (23.3 ± 22; 95% CI: 12.5- 40.2), adjectives (18.6±14; CI 95%: 10.0- 27.2) Among the auditory factors, the auditory age was positively correlated (Rho=0.65, p≤0.05) with the number of words produced by minors. In turn, among the socio-environmental factors, the time in therapy and the schooling of the children were positively associated with the number of grammatical elements reported (p≤0.05). Finally, it was observed that the daily hours of cochlear implant use were directly related to the parents' years of schooling (Rho=0.7, p≤0.05). The development of language depends on the functionality and integrity of hearing, although there are also factors that influence to different degrees and measures. If there is a decrease in hearing, a sensory disturbance, language is affected. Therefore, in the case of children who use cochlear implant, auditory factors condition differences in language development.

Keywords: ***cochlear implant, language development, auditory factors, socio-environmental factors, acquisition of language.***

I.- INTRODUCTION

Oral language acquisition occurs within a sensitive stage with a temporal and physiological limit ranging from zero to three years of age during which the child has an increased disposition towards certain behaviors, such as the acquisition of the language in which he is immersed. This process is particularly rapid when there is no sensory or neurological alteration.[1,2] Language development can be modified by lack of hearing. Because language does not only depend on perception, what is heard needs a system of analysis, other authors recognize the suprasegmental and syntactic structures in which the sequences of syllables of the ventral pathway and phonemes are organized. It requires a set of neural networks that involve both pathways and connect them [3,4].

On the other hand, the decrease in hearing capacity profoundly impacts the quality of life of those who suffer from it, affecting not only the ability to communicate with peers but also alters social and educational development and finally the ability to insert into society. [5]

Currently, there are figures ranging from 1-2 out of every 1,000 children born with profound deafness. [6,7] So hearing loss, especially in its most severe forms, is associated with specific developmental risks. Worldwide, studies have been implemented that have demonstrated the impact of the early diagnosis and management of this pathology on the subsequent development of both language and speech, affecting various daily activities such as academic performance and social welfare. Currently, screening methods have helped to establish a more accurate early diagnosis of the intensity and nature of hearing loss before 3 months of age. Outreach in early diagnosis has been crucial in the advancement and development of public health. [8]

In the ‘90s, a technological breakthrough was achieved that changed the landscape of the rehabilitation of the deaf, the cochlear implant (CI), which made available medical treatment for children with severe to profound neural sensory hearing loss. This device has an external component that processes sound into electrical signals that are sent to a set of receptors and an internal electrode that stimulates the auditory nerve. [4,7,9]

The use of this device has been a very important aid both in rehabilitation, as well as in the habilitation of children who have severe hearing loss. It is important to note that children with HF are able to acquire auditory recognition patterns and develop communicative functions. However, they need more information than they receive. As a result, there are huge individual differences in the degree to which deaf children fully benefit from early intervention with cochlear implantation. Children with similar audiological profiles receiving the same intervention often have drastic differences in communication, language, social, cognitive, educational, literacy, and professional outcomes. [5,6,10]

Recent studies suggest that the processing of linguistic and indicial information is intertwined in a complex way in individuals with normal hearing. [3,6,11] Rather than "normalizing" speaker variations to abstract common phonetic properties, evidence suggests that the listener integrates the linguistic and indexical properties of the speech signal. [12] advocates a conceptual link between the symbolic linguistic properties of speech and the simultaneously encoded vocal source. From this point of view, the listener uses the indexical properties of the vocal source, such as gender, emotion, and speech speed, to facilitate a phonetic interpretation of the linguistic content of the message. The extent to which cochlear implants allow children to make use of the linguistic and indexical properties of speech may influence not only the development of spoken language but also their ability to function successfully in an auditory world. [3,8,13]

Despite remarkable advances in cochlear implant technology, many children lag far behind their peers in speech and language skills. So, our goal was to assess the auditory and socio-environmental factors involved in the language development of Mexican children who use cochlear implants.

II.- MATERIAL AND METHODS

This is a cross-sectional and descriptive study, where13 children who used Cochlear Implant were selected at the Luis Guillermo Ibarra Ibarra National Rehabilitation Institute (INR LGII) in the period 2010-2015. The selection criteria were that they had normal hearing at the time of the evaluation, with the Spanish language as the main language in the family; normal cognitive level, and absence of associated disorders or socioeconomic difficulties. Audiological characteristics and language development were assessed through standardized tests, to measure silent speech perception, comprehension and lexical production. The development of the understanding of emotions was evaluated using the MacArthur-Bates Communicative Skills Inventory (CDI) to measure the grammatical and functional production of minors, as well as a parental questionnaire to collect information on the auditory and socio-environmental factors of the participants.

The statistical analysis was performed through the Spearman range correlation coefficient, to analyze the relationship between auditory and socio-environmental factors obtained and study the relationship between personal and audiological characteristics; an analysis of central tendency, frequencies, and percentages was performed to describe the sociodemographic characteristics of the participants. The SPSS v 23 program was used for data analysis (SPSS Inc., Chicago, IL), for all analyses an alpha of 5% was considered significant.

III.- RESULTS

We analyzed 13 cases of child HF users. The average chronological age of the children studied was 5.87 years, with a range of 2.7 years to 10.2 years. The male sex was the predominant one with 69% of the cases and the female one with 31%. Motor development was adequate in all participants. The IQ of the sample was found in the range (95%) of 79.6-91.5

Auditory Factors

The average age of implantation was 3.87 years with a range of 2.1 to 5.6 years of age. 46.15% of the children had implantation in the right ear and 53.85% in the left; the meantime of use of the hearing aid was 11.3 months with an average use of 12.9 hours per day. At the time of the study, the children's mean hearing age was 43.9 months in time of cochlear implant use.

The socio-environmental data of the parents of the minors are shown in Table 1. The last degree of studies of 46 and 31% of the parents, respectively, was a bachelor's degree, while 23% attended high school in both cases. As for the sample's NSE, 31% of households were classified in level 1, 23% in level 2, 15% in level 3, and the remaining 31% in level 4. On average, parents and children interact at home 9.3 hours a day (95% CI: 7.0-11.5) with a minimum of 3 hours and a maximum of 12. 46% of the children had primary education, 39% kindergarten and 15% had a kindergarten education. They received on average 36.6 months of therapy (95% CI: 20.4-52.8).

Table 1. Sociodemographic data of the parents of children with Cochlear Implant**.**

Socio-environmental factors	Average in years (SD)
Mother's age	35.5 (6.9) years
Father's age	37.0 (6.8) years
Mother's schooling	16 (4.1) years
Father's schooling	15 (3) years
Interaction time at home	9.3 (3.7) hours

Language development

According to Figure 1, the mean number of words produced by children was 207.3 (95% CI: 122.4-292.2). They were able to understand 156.7 words on average (95% CI: 70.6-242.9).

Depending on the lexical category, as shown in Figure 2, the largest number of words they produced were nouns (112.62 ± 77; CI 95%: 65.6-159.6), followed by verbs (23.3 ± 22; 95% CI: 12.5- 40.2), adjectives (18.6±14; 95% CI: 10.0- 27.2) and pronouns (9.5±10.2; 95% CI: 3.3- 15.7). The most frequent verbs were: *give, eat, look* and *finish.* Similarly, the most prevalent adjectives were: *blue, yellow, green, red,*

large, and *small.* Finally, the most commonly used pronouns were: *mine, me,* and *you.*

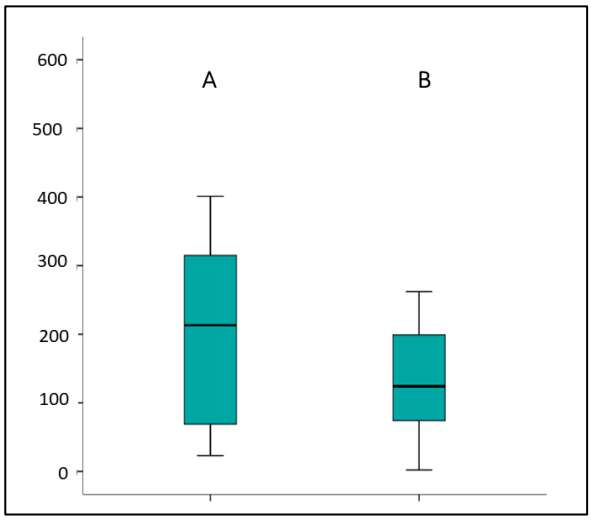

Figure 1. A) Number of words produced by children with Cochlear Implant. B) Number of words comprising.

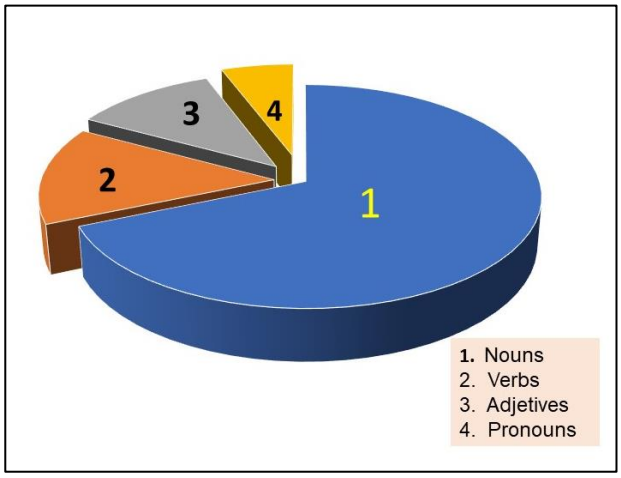

Figure 2. Lexicon produced by children with Cochlear Implant.

Correlations

The hearing age of the children was directly related to the time of therapy, as well as to the school years studied (Table 2). Similarly, a significant positive correlation (p≤0.05) was found between auditory age and the number of words they say, specifically articles, nouns, verbs, adjectives, temporal referents*(morning, night*, and *early),* and questions (how *which, where is, why, what* and *who*).

Time in therapy also correlated positively (p≤0.05) with the number of words children say, particularly with the number of verbs, adjectives, and time referents. The daily hours of use of the CI were directly correlated (p≤0.05) with the years of schooling of both parents and the hours of interaction at home.

Finally, positive correlations (p≤0.05) were found between the years of schooling studied and all the grammatical elements studied. The strongest relationship was found with the number of articles. Similarly, schooling was directly associated with the age of the mothers.

Table 2. Correlation of the auditory age of minors with the time of therapy, as well as with the school years studied, Rho=0.7**.

Rho	Hearing age	Time in therapy	Daily hours of use	Years of the child's schooling
Hearing age		.65*		.78**
Number of words you say	.65*	.59*		.61*
Number of words you understand	-.60*			-.73**
Nouns	.74**			.56*
Body				.59*
Utensils				.57**
Furniture				.66*
Places				.74*
Verbs	.74**	.61*		.71**
Adjectives	.70**	.61*		.67*
Time	.66*			.70**
Questions	.72**	.70**		.68*
Articles	.77**			.80**
Mother's age				.68*
Years of mother's schooling			.76**	
Years of the father's schooling			.71**	
Hours of interaction at home			.67	

IV.- DISCUSSION

The present study described the auditory and socio-environmental factors involved in the language development of Mexican children who use cochlear implants, with a population of 13 children aged 2.7 years to 10.2 years with hearing loss.

The data obtained from the analysis carried out show that the differences that exist lie in the order of appearance of the words. Implanted children first produce nouns in greater numbers, then verbs, and then attributes or adjectives. Instead, hearing children produce first nouns, then attributes, and then verbs. [8,13,14]

As for the development of language, we find a greater number of verbs, followed by the number of nouns. This constant is one of the most present differences in the process of language acquisition in children who use cochlear implants in relation to children with normal hearing.

It has been described that at 28 months of age competent children determine the syntactic relationships in which verbs are presented. They can also use the order of the elements of the sentence to extract the role of the agent involved in the verb. [15,16,17,18]

It is important to note that verbs have a central role in the grammar of the language, have a relationship between the meaning and structure of the sentence, and, in addition, allow to infer the meaning of other words. Mouvet et. al, 2013. [19] At the age of three, it is observed that children can relate an object to the actions or functions it performs. It is in that period that the verb tenses begin to appear. The authors point out that the use of verbs requires a broader and more complex decision and cognitive selection, since, unlike nouns, they have an argument structure. [17,20,21]

In children who use Cochlear Implant, the possible explanation for the use of more verbs is that the perception of actions bilaterally activates the premotor regions, but the understanding of sentences involving physical actions only activates the left premotor regions. [21,22]

The use of verbs not only involves morphological and grammatical processing, but it also involves a major executive and attentional component. For example, in this case, the most frequent verbs in production are transitive verbs, that is, those that require three arguments. subject and an object and an agent. [23,24,25]

Based on our results it becomes evident that the language development of implanted children is different from that of hearing children because of the type of words they produce and the order of appearance, where functional lexical elements are poorly produced.

The possible explanation lies in the lack of information in the dorsal and ventral pathways causing little production of functional lexical elements.[22,24]

Different authors have described the importance of these pathways in language development. [25,26,27,28]

Our results strongly support a link between linguistic properties in perceptual speech analysis. These two channels of information seem to be processed together in parallel by the auditory system and are inseparable in perception. Better speech performance. Children with better speech perception demonstrated better-spoken language, earlier academic incorporation, and placement in school. [22,28,29]

On the other hand, the evaluation of intelligence in deaf people entails a series of challenges for the evaluator, since children have social, cognitive, and communication skills below their hearing peers. Most tests are aimed at the hearing population.

In a study of children between 4 and 10 years old, it is inferred that, the lower the level of hearing, the lower the score. Silva and Deaño (2008) concluded that the level of hearing impacts the functioning of different cognitive processes. [30,31] Just as a description of the population.

Barragán and Lozano, 2011 mentions that language development is directly related to cognitive factors. This could explain the average IQ of the children in this study, which is lower than average, and their lower performance in language development. [32]

Another study by Chen et al. in 2016 concluded that deaf children with unilateral implantation have a higher IQ. However, they have noticed that deaf children, in general, have difficulties at the cognitive level. [30,31,32]

We also observe variations in lexical development in terms of functional categories, as these are less compared to those produced by contemporary listeners. At two years they make the distinction between verbs and nouns, and nouns and adjectives it is also expected that this number will be lower than that of the merely lexical grammatical categories. [33, 34, 35].

For syntax to exist, 50 words are needed in all languages. Therefore, the child can begin to combine pairs of words. Clark (1993) refers that within these words there are nouns, attributes or adjectives, and, to a lesser extent, verbs. [36]

According to Clark (1993), children elaborate semantic frameworks by joining words whose meanings are related; in addition, they analyze the structure of the word to identify roots and affixes and their relationship with meaning to create new words. Likewise, they begin to isolate word forms and assign them meaning, marking conceptual grammatical categories that represent classifications of objects, relationships, states, activities, and events, which the Mc Arthur Inventory evaluates.

Maternal age and paternal age were related to deafness because fathers postpone paternity and motherhood. The reproductive age has been modified by the sociocultural level, because the higher it is, the higher the reproductive age. Paternity can also be postponed because you have a family member with a disability. [37,38].

The child who uses Cochlear Implant has a language development of his own and is different from that of the hearing child. The sensitive period for the appearance of the oral language could depend on the temporal area, specifically the ventral pathway, since, without the information that is processed in it, the development of the language is affected. In the brain, two neural networks are developed that are responsible for the analysis of acoustic information. With Cochlear Implant, the ventral pathway develops, while the dorsal pathway develops slowly, as the Cochlear Implant does not contribute to the sufficient processing of the required sound information. Therefore, the child user of Cochlear Implant depends a lot on all the information in the environment [39,40].

Finally, we see how language development can be modified by lack of hearing. Because language does not only depend on perception, what is heard needs a system of analysis, Other authors to recognize the suprasegmental and syntactic structures in which the sequences of syllables of the ventral pathway and phonemes are organized. It requires a set of neural networks that involve both pathways and connect them. [41,42]. Children with Cochlear Implant are able to acquire auditory recognition patterns and develop communicative functions. However, they need more information than they receive while a significant

correlation was found between word production and time in therapy [43].

V.- CONCLUSION

Language development depends on the functionality and integrity of hearing, although there are also factors that influence different degrees and measures. If there is a decrease in hearing, a sensory disturbance, language is affected. Therefore, in the case of children who use Cochlear Implant, auditory factors condition differences in language development.

VI.- ETHICAL RESPONSIBILITIES

Protection of people. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of the data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Conflict of interest: The authors declare that there is no conflict of interest.

Suggestions for rehabilitation and contributions

Success stories in the use of Cochlear Implant could be explained by the integrity of hearing up to the moment of birth since the information processed in utero fulfilled its function. It is proposed to investigate, although not in all cases, language development in children with adverse factors at birth (HAF) to determine whether it is a determining factor or not.

If the hearing loss is due to FAN, the auditory system will have received adequate sound information and there will be physiological anatomical bases for oral language to develop.

Therefore, it is suggested to analyze the success stories, taking into account the etiology of hearing loss.

It is, therefore, necessary to implement a methodology for teaching Spanish appropriate to the characteristics of the population in question.

Suggestions, recommendations

Therapy needs to be based on each child's skills and characteristics.

The points that Moreno Torres and Fredes propose are: (quote)

Work specifically on phonological processing.

- Encourage auditory memory, working memory.
- Use rhymes.
- Use pseudowords.
- Practice reading and writing.

In addition, we suggest:

- Encourage the use of verbs, do not call so much, and promote narration.
- Promote the use of nouns that refer to abstract things.
- Use discretionary visual support, interaction games, turn-taking, and role-playing.
- Stimulate theory of mind (TOM).
- Do exercises or activities that promote analytical activities and phonological processing.

With the research carried out and based on the results obtained in the understanding and production of words or functional lexical elements, it is recommended to include visual clues in the rehabilitation of children who use Cochlear Implant, especially in the early stages of rehabilitation, since the dorsal and ventral pathways, in addition to linguistic auditory information, they also process visual information. Visual information can give clues that promote the information necessary to achieve linguistic competence.

It is proposed to analyze the success stories of children who use a Cochlear Implant to evaluate the factors involved. First, to study whether there was FAN, because, if so, the auditory system received sound information and was intact at birth, which would help in the process of language development.

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