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Auditory and language categories in children with cochlear implants

Categorias auditivas e de linguagem em crianças usuárias de Implante Coclear

Categorías auditivas y de lenguaje en niños con implantes cocleares

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Abstract

Introduction: Cochlear implant benefits the individual with hearing loss both in language development and in improving the perception of speech sounds. Successful cochlear implant surgery, coupled with adequate stimulation and correct monitoring, provide a better development of children's hearing and language skills. In this sense, in addition to controlling the variables of age at surgery and access to speech therapy for the development of auditory and language skills, knowing the families and how it influences the children's performance is extremely valid, as it can improve the reception and better target counseling. **Objective:** To verify the relationship between the categories of hearing and language considering the age at surgery and the relationship between the categories of hearing, language and family involvement in children with cochlear implants. **Method:** The studied sample consisted of 15 children aged between 2.2 and 8.3 years. Questionnaires were used that measured auditory perception, speech perception and language use by children. The family involvement assessment scale was also applied to help categorize children based on hearing and language. **Results:** There was a significant relationship between hearing and family involvement and hearing and language categories. There was no relationship between the child's age at surgery and the hearing and language categories. There was also no relationship between family involvement and language. **Conclusion:** The child's age at device implantation was not

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Authors' contributions:
NFE: study conceptualization, methodology, and data collection.
JHSM: article preparation for publication.
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related to the classification of hearing and language categories. Children from more participatory families presented better rates of auditory development.

Keywords: Hearing loss; Hearing; Language Development; Cochlear Implantation; Rehabilitation.

Resumo

Introdução: O implante coclear beneficia o indivíduo com perda auditiva tanto no desenvolvimento da linguagem, quanto no aprimoramento da percepção dos sons da fala. A cirurgia do implante coclear bem-sucedida, somada à estimulação adequada e ao monitoramento correto, proporcionam um melhor desenvolvimento das habilidades auditivas e de linguagem das crianças. Nesse sentido, além de controlar as variáveis de idade na cirurgia e acesso à terapia fonoaudiológica para o desenvolvimento das habilidades auditivas e de linguagem, conhecer as famílias e de que maneira ela influencia no desempenho das crianças é extremamente válido, pois pode melhorar o acolhimento e direcionar melhor o aconselhamento. **Objetivo**: verificar a relação entre as categorias de audição e de linguagem considerando a idade na cirurgia e a relação entre as categorias de audição, linguagem e de envolvimento familiar em crianças usuárias de implante coclear. **Método**: A amostra estudada foi composta por 15 crianças com idade entre 2,2 e 8,3 anos. Foram utilizados questionários que mensuravam a percepção auditiva, a percepção de fala e o uso da linguagem pelas crianças. Foi aplicada também a escala de avaliação do envolvimento familiar para o auxílio na categorização das crianças a partir da audição e da linguagem. **Resultados:** Houve relação significante entre categorias de audição e envolvimento familiar e audição e linguagem. Não houve relação entre a idade da criança na cirurgia e as categorias de audição e de linguagem. Também não houve relação entre o envolvimento familiar e linguagem. **Conclusão**: A idade da criança na implantação do dispositivo não se relacionou com a classificação das categorias de audição e de linguagem. As crianças de famílias mais participativas apresentaram melhores índices de desenvolvimento auditivo.

Palavras-chave: Perda Auditiva; Audição; Desenvolvimento da linguagem; Implante Coclear; Reabilitação.

Resumen

Introducción: El implante coclear beneficia al individuo con pérdida auditiva tanto en el desarrollo del lenguaje como en la mejora de la percepción de los sonidos del habla. La cirugía exitosa de implante coclear, aunada a una estimulación adecuada y un correcto monitoreo, brindan un mejor desarrollo de las habilidades auditivas y del lenguaje de los niños. En este sentido, además de controlar las variables edad de la cirugía y acceso a logopedia para el desarrollo de las habilidades auditivas y del lenguaje, conocer a las familias y cómo influye en el desempeño de los niños es de gran validez, ya que puede mejorar la recepción y mejor asesoramiento de destino. **Objetivo:** Verificar la relación entre las categorías de audición y lenguaje considerando la edad en la cirugía y la relación entre las categorías de audición, lenguaje y envolvimiento familiar en niños con implante coclear. **Método:** La muestra estudiada estuvo constituida por 15 niños con edades comprendidas entre 2,2 y 8,3 años. Se utilizaron cuestionarios que midieron la percepción auditiva, la percepción del habla y el uso del lenguaje por parte de los niños. También se aplicó la escala de evaluación de la participación familiar para ayudar a categorizar a los niños en función de la audición y el lenguaje. **Resultados:** Hubo una relación significativa entre las categorías de audición y participación familiar y audición y lenguaje. No hubo relación entre la edad del niño en el momento de la cirugía y las categorías de audición y lenguaje. Tampoco hubo relación entre la participación familiar y el lenguaje. **Conclusión:** La edad del niño en el momento de la implantación del dispositivo no se relacionó con la clasificación de las categorías de audición y lenguaje. Los niños de familias más participativas presentaron mejores índices de desarrollo auditivo.

Palabras clave: Perdidá Auditiva; Audición; Desarrollo del Lenguaje; Implantación Coclear; Rehabilitación.

Introduction

Cochlear implants (CI) help individuals with hearing loss develop language and improve speech sound perception. Recognized as one of the great technological advancements in the last decades, the objective of CI is to directly stimulate the auditory nerve with electrodes placed in the cochlea. It can be used by individuals of different age groups with severe and/or profound sensorineural hearing loss who did not benefit from previous use of hearing aids (HA).[1]

CI use has been generally associated with better results in auditory perception and language and reading development, in comparison with children who use HA.[2]

The earlier the brain receives meaningful sounds, the greater conditions it will have to produce good results due to the functional plasticity of the central nervous system and decreased sensory deprivation. The speech-language-hearing process in children with CI begins by conducting them regarding the meaning of the sounds they hear and associating them with the sound source. As this development progresses, children increasingly rely on their auditory pathway.[3]

Studies have demonstrated that children implanted before 3 years old have better long-term speech perception results than those implanted after 3 years old. Successful CI surgeries and adequate stimulation and monitoring provide better development of hearing and language skills in children with hearing loss.[4,5]

Children's age at the implant is one of the variables that can influence CI performance. Hence, it must be always discussed when counseling families.[4,5]

A review of the literature on post-CI language development analyzed longitudinal studies and found that receptive and expressive language increasingly developed over time in all children with CI. The study concluded that CI proved to be effective in the language development of children with hearing loss when accompanied by speech-language-hearing therapy – the earlier the surgery, the more robust the results in syntax and vocabulary.[2]

Oral language development, which can be measured with various tools, is one of the greatest concerns of families whose children use CI. One of these tools is the Meaningful Use of Speech Scale (MUSS), proposed by Robbins in 1992. It has good reliability and validity, confirming its usefulness to assess oral language in the everyday life of children with CI.[6] People's hearing must be ensured for them to develop oral language as expected for their age. Hence, the Infant Toddler Meaningful Auditory Integration Scale (IT-MAIS) and Meaningful Auditory Integration Scale (MAIS) speech perception questionnaires and Glendonald Auditory Screening Procedure (GASP) assessment proved to be effective instruments to assess auditory performance and results with CI.[7]

Moreover, weekly speech-language-hearing therapy is essential to direct the children's rehabilitation process, and the involvement of their families in this process is a factor that must be considered, particularly regarding speech/hearing therapy. The families' participation in developing and stimulating children during their therapeutic process can be assessed with the Family Involvement Rating.[8,9]

Even if the same assessment instruments were used in children, countless variables must be controlled, making it difficult to compare different studies. Such variables include the age at surgery, auditory age, adherence to speech-language-hearing therapy, family involvement in the therapeutic process, and so forth. This requires further studies, always mentioning and considering the different variables to be critically analyzed, given the specificities in each sample.

It has been increasingly demonstrated that family involvement is essential to the hearing rehabilitation process, as children sometimes cannot attend speech-language-hearing therapy more than once a week, due to family financial reasons or the high demand for public health services in Brazil. Hence, families are great allies and language stimulation models for children with hearing loss.

Thus, besides controlling variables of age at surgery and access to speech-language-hearing therapy for the development of hearing and language skills, knowing the families and how they influence children's performance is greatly important, as it can improve healthcare and better direct counseling.

Given the above, the objective of this study was to verify the relationship between hearing and language categories, considering the age at surgery and the relationship between the hearing and language categories and family involvement in children with CI.

Method

This observational, descriptive, cross-sectional study was analyzed and approved by the Ethics Committee under number 2.067.502. All parents/guardians read and signed an informed consent form. The sample was formed based on the following inclusion criteria: children having speech-language-hearing therapy in a program with a speech/hearing approach and using unilateral CI for at least 6 months. Patients with previously diagnosed neurological comorbidities were excluded.

Based on these criteria, the sample comprised 15 children aged 2.2 to 8.3 years, with a mean age of 4.4 years. Four of them were females (26.7%) and 11 were males (73.3%).

Chart 1 shows the sample characterization in this research regarding sex, age (years), age at CI activation (years) occurring 30 days after the surgery, time of CI use (years), etiology, the brand of the speech processor, CI side, and contralateral HA use.

Chart 1. Sample characterization

Subject	Sex	Age (Years)	Age at CI activation (years)	Time of CI hearing experience (years)	Etiology	CI side	HA use
1	M	2.6	1.5	1.1	Unknown	LE	yes
2	M	2.3	1.8	0.5	Genetic	RE	no
3	M	3	1.3	1.9	Genetic	RE	no
4	M	3.2	1.5	1.9	Genetic	LE	yes
5	F	3.3	1.1	2.4	Unknown	LE	yes
6	M	2.8	2.2	0.6	Genetic	LE	no
7	F	3.9	1.9	2	Unknown	RE	yes
8	M	3.4	2.6	1.4	Meningitis	LE	yes
9	F	4.6	3.4	1.2	Unknown	RE	yes
10	M	4.8	3.4	1.4	Unknown	LE	no
11	M	5.1	3.8	1.5	Unknown	LE	yes
12	M	5.2	2.7	2.7	Unknown	LE	yes
13	F	5.6	3.6	2	Unknown	RE	yes
14	M	7.8	5.8	2	Cytomegalovirus	LE	yes
15	M	8.3	4.2	4.5	Unknown	LE	yes
MEAN	-	4.4	2.7	1.8	-	-	

In the methodology used in this study, children up to 4 years old were submitted to IT–MAIS[10], and those older than 4 years were submitted to MAIS questionnaire[11,12]. Speech perception tests were made with GASP[13] in children above 5 years old and the Minimum Hearing Capacity Assessment Test (TACAM, in Portuguese)[14] in children up to 5 years old. Oral language use was assessed with the MUSS questionnaire[15,16].

Based on these questionnaires and assessments, children were classified into one of the following six hearing categories[17]: Category 0- Does not detect speech; Category 1- Detects speech; Category 2- Differs words based on suprasegmental cues; Category 3- Begins closed set identification (identical words in duration, but with multiple spectral differences); Category 4- Identifies words by recognizing vowels in a closed context; Category 5- Identifies words by recognizing consonants in closed contexts; Category 6- Recognizes words in open sets.

Based on responses to MUSS, the therapist's perception and observation, and the parents' report, the children were classified into one of the following five language categories[18]: Category 1- The child does not speak and may present undifferentiated vocalizations; Category 2- The child speaks only isolated words; Category 3- The child builds sentences with two or three elements; Category 4- The child builds sentences with four or five words

and begins using connectives; Category 5- The child builds sentences with more than five words and conjugates verbs, uses connectives, and is fluent in oral language.

Family involvement in the therapeutic process was classified with the Family Involvement Rating[8], which has five items:

Limited participation. The family has significant tensions in their lives that might affect the child's needs (e.g., domestic abuse and the lack of a home) and have a limited understanding of deafness and its consequences. Participation can be sporadic or little effective. Parent/child communication is limited to the most basic needs.

Below-average participation. The family strives and suffers to accept the child's diagnosis. It may inconsistently attend healthcare and place and maintain HA at home and school. It may also have significant tensions in their lives that interfere with consistent work at home. Caring for the child poses daily challenges to the family, and only basic communication interactions are promoted. There is a lack of fluency in how they communicate with the child.

Median participation. Relatives strive to understand and accept the diagnosis and participate in most sessions/meetings. Overloaded schedules or family tensions may limit opportunities to do at home what they have learned. Caring for the child may be challenging for the family. They participate in planning but generally submit to the professionals' opinion. They seek to protect the child, but efforts are misdirected. Specific family members (such as the mother) may have most of the responsibility to carry out the child's communication needs, though only in basic skills. They intend to use language expansion techniques but need constant support and direction.

Good participation. Family members adapt better than the average to the child's deafness, regularly attending sessions and parents' meetings. They have an active role (perhaps not the main one) in planning clinical and educational objectives; they are good language models and strive to use the techniques at home. Some family members are considerably skillful to communicate according to the child's mode and/or use language stimulation techniques. They make efforts to involve extended family members.

Ideal participation. The family seems to have adapted well to the child's deafness and can put in perspective their incapacities in the family context. Their members regularly attend and actively participate in sessions and meetings; they also independently seek information. They defend including the child in health and educational services, etc. Some become highly effective as conversation partners and are consistently good language models; they also become fluent in the child's mode of communication and can apply language expansion techniques. Extended family members are involved and give additional support to the child.

The families were classified by their respective therapists, who had extensive contact with the parents and children.

Language categories were divided into 1 to 2 and 3 to 5 due to the sample size and because they separate initial (categories 1 and 2) from more complex oral language development skills (categories 3, 4, and 5). Hearing categories were divided into 0 to 1 and 2 to 6 also due to the sample size and in order to separate into categories 0 and 1 children with low hearing perception development, and into 2 to 6 those with more advanced and fully developing hearing perception.

Lastly, the family involvement rating was divided into 1 to 3 and 4 to 5. The first group (categories 1 to 3) was characterized by participation below the expected, as category 3 is related to median participation; the second group (categories 4 to 5) was characterized by adequate participation, as they encompass families with good and ideal participation.

Data were statistically analyzed with the independence chi-square test; the significance value was set at 5% or 0.05.

Results

The sample comprised 15 children who used unilateral CI, with various hearing loss etiologies.

The age at device activation ranged from 1.1 to 5.8 years, with a mean of 2.7 years, which is equivalent to 32.4 months. The time of CI use ranged from 0.5 to 4.5 years, which is respectively equivalent to 6 and 54 months, with a mean of 21.6 months of use. The type of speech processor varied among the children – 67% (n = 10) used a speech processor manufactured by Cochlear, and 33% (n = 5), by Advanced Bionics.

The results of the IT-MAIS or MAIS questionnaires and GASP or TACAM speech perception

and language tests are shown in the chart below. The speech perception tests (GASP and TACAM) were not analyzed in this study; they were applied to categorize the children's hearing and language at the time of the study.

Chart 2. Results of the questionnaires and speech perception and language tests

Subject	Sex	Age	Hearing category	Language category	Family involvement	MUSS (%)	IT-MAIS/ MAIS (%)
1	M	2.6	1	2	5	50	75
2	M	2.3	1	1	3	22.5	50
3	M	3	4	2	4	32.5	52.5
4	M	3.2	1	3	2	52.5	85
5	F	3.3	6	3	4	90	90
6	M	2.8	1	1	2	32.5	62.5
7	F	3.9	2	3	2	50	90
8	M	3.4	1	2	4	47.5	72.5
9	F	4.6	1	1	2	57.5	65
10	M	4.8	1	3	3	47.5	87.5
11	M	5.1	1	1	3	50	67.5
12	M	5.2	6	5	5	97.5	95
13	F	5.6	4	3	4	85	97.5
14	M	7.8	6	3	4	95	92.5
15	M	8.3	6	5	5	97.5	97.5
MEAN	-	4.4	2.8	2.5	3.5	60.5%	79%

The relationship between the age at surgery and the hearing and language categories are respectively shown in Tables 1 and 2. The statistical analysis did not demonstrate a relationship between the age at surgery and the hearing and language categories.

Table 1. Association between age at surgery and hearing categories.

	Age at surgery (years)		
Hearing category	< 2	2 to 3.5	> 3.5
0 or 1	3 (37.5)	4 (50.0)	1 (12.5)
2 to 6	3 (42.8)	2 (28.6)	2 (28.6)
p-value = 0.626			

Independence chi-square test

Table 2. Association between age at surgery and language categories.

	Age at surgery (years)		
Language category	< 2	2 to 3.5	> 3.5
1 or 2	3 (42.9)	3 (42.9)	1 (14.2)
3 to 5	3 (37.5)	3 (37.5)	2 (25.0)
p-value = 0.875			

Independence chi-square test

The relationships between the family involvement rating and the language categories, between family involvement rating and hearing categories, and between hearing and language categories are respectively shown in Tables 3, 4, and 5. No evidence was found of a relationship between family involvement rating and language categories (Table 3). There was evidence of a relationship between hearing categories and family involvement rating and between hearing and language categories (respectively Tables 4 and 5).

It was verified that the better the hearing category, the better the language category.

Table 3. Combined distribution of family involvement and language categories.

	Language category		
Family involvement	1 or 2	3 to 5	TOTAL
1 to 3	4 (57.1%)	3 (42.9%)	7 (100%)
4 or 5	3 (37.5%)	5 (62.5%)	8 (100%)
p-value = 0.447			

Independence chi-square test

Table 4. Combined distribution of family involvement and hearing categories.

	Hearing category		
Family involvement	0 or 1	2 to 6	TOTAL
1 to 3	6 (85.7%)	1 (14.3%)	6 (100%)
4 or 5	2 (25.0%)	6 (75.0%)	8 (100%)
p-value = 0.019*			

* Statistically significant values (p ≤ 0.05) – Independence chi-square test

Table 5. Combined distribution of language and hearing categories.

	Hearing category		
Language category	0 or 1	2 to 6	TOTAL
1 or 2	6 (85.7%)	1 (14.3%)	6 (100%)
3 to 5	2 (25.0%)	6 (75.0%)	8 (100%)
p-value = 0.019*			

* Statistically significant values (p ≤ 0.05) – Independence chi-square test

Discussion

This research sample comprised 15 children with unilateral CI (11 using contralateral HA), with a time of CI use ranging from 6 months to 4 years and 5 months, with a mean of 1.8 years. All participating children were classified into hearing and language categories and family involvement ratings to verify the relationship between these variables.

As shown in Tables 1 and 2, there was no statistical relationship between the children's age at surgery and the hearing and language categories. This result diverges from the literature, as age at surgery is described as one of the variables that influence CI performance.[19,20,21] The absence of a statistical relationship may be due to different factors, such as the sample size, the great age range at implant, and other variables that influence performance in children with CI (e.g., adherence to speech-language-hearing therapy, the quality of device programming, parental stimulation, and the continuity of the stimulation work at home.[22,23]

The result of this study further reinforces the need for considering other variables that influence children's performance, besides age at CI surgery. Age at implant can ensure early access to speech sounds, but children's benefits from such access depend on the parents' participation, effective device use, and speech-language-hearing therapy.

In different studies, CI proved to be effective in the language development of children with hearing loss when combined with speech-language-hearing therapy, achieving more advanced results in language skills when surgeries are performed earlier. The need for standardized validation and comparison instruments was highlighted to clarify language development in this population more systematically. [2,27]

One of the hypotheses in the present study was to demonstrate the importance of family involvement and its relationship with language categories. However, this relationship was not observed as expected (Table 3). The number of children assessed may not have been enough to prove this relationship.

Oral language development results are a consequence of effective stimulation of hearing skills, and they may appear later in some children. In that case, longitudinal follow-up of children with CI is the ideal to verify language development and family involvement in the treatment, aiming to improve this one with counseling in the process.[24]

Moreover, the younger the child at CI surgery and the greater the time of CI use, the better their oral language development.[25] Hence, controlling these variables and following up on the children over time are excellent ways to verify CI results.

Family involvement in the therapeutic process directly influenced the children's good results in hearing categories. This relationship (Table 4) reinforces the importance of family guidance and counseling throughout the children's hearing rehabilitation process, especially regarding motivation in the treatment and encouragement to use the device [3,5,17]. Thus, family guidance and counseling during the therapeutic process are greatly important to developing hearing skills, aiming at the optimal use of the hearing device and better communication performance.[22,23,24]

Table 5 demonstrated a statistical correlation between hearing and language categories, indicating that hearing and language development are closely related. Another study even pointed out that hearing and language skills increasingly improve over time and that there may be differences between individuals depending on the therapy mode.[26]

Possibly, relationships were found between hearing and language categories and between hearing categories and family involvement ratings, but not between language categories and family involvement ratings because language development can be out of step with hearing development [28].

For instance, children without hearing loss develop language from birth, processing and storing linguistic repertoires to which they have access via their auditory pathway during various repeated communication interactions[7]. Children with CI likewise go through these stages: they first develop hearing and then speech.

Hearing perception indices in a study were greater than the language development indices, indicating that CI effectively improves the patients' hearing skills, while directed training is necessary to develop and improve speech.[26]

This study had limitations, such as the broad age range assessed in a small sample and the cross-sectional design instead of a longitudinal one, which would provide further information on the children's performance and progress.

Therefore, further studies on the topic are needed to relate aspects of the daily time of device use, programming possibilities, and opportunities of using hearing and oral language outside the therapy setting to expand the knowledge about post-CI hearing rehabilitation.

Conclusion

This study did not associate the language and hearing categories with the children's age at surgery or family involvement ratings with language categories. As for the association between hearing and language categories, the higher the scores in hearing categories, the higher those in language, demonstrating that oral language development depends on hearing development. Furthermore, an association was identified between hearing categories and family participation; hence, children whose families participated more in the therapeutic process had higher hearing perception scores.

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