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Glendonald Auditory Screening Procedure (GASP): clinical markers of the development of auditory recognition and comprehension abilities in children using cochlear implants

Glendonald Auditory Screening Procedure (GASP): marcadores clínicos de desenvolvimento das habilidades de reconhecimento e compreensão auditiva em crianças usuárias de implante coclear

Bárbara Cristiane Sordi Silva[1,2]
Adriane Lima Mortari Moret[1,2]
Leandra Tabanez do Nascimento Silva[2]
Orozimbo Alves da Costa[1,2]
Kátia de Freitas Alvarenga[1,2]
Mariane Perin da Silva-Comerlatto[2]

Keywords

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Child
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ABSTRACT

Purpose: To verify the influence of the age of implantation in the development of closed-set auditory recognition and auditory comprehension abilities in children using unilateral cochlear implants (CI), comparing distinct groups and determining clinical markers. **Methods:** Participants were 180 children operated and activated until 36 months of age and who used a CI for at least 60 months. Abilities of auditory recognition in closed-set and auditory comprehension were analyzed through the GASP Tests 5 and 6. The influence of age of implantation was investigated with three groups of children: implanted before 18 months (G1), between 19 and 24 months (G2) and between 25 and 36 months of age (G3). **Results:** There was no statistically significant difference when comparing the three groups. Children progressively developed auditory abilities, presenting auditory recognition ability together at approximately 41±4 months of CI use and auditory comprehension at 53±4 months. **Conclusion:** There was no correlation between hearing performance and age of implantation for children implanted before 36 months of age. For the abilities of auditory recognition and comprehension, the clinical marker was 41±4 and 53±4 months of auditory age, respectively. Therefore, it is expected that, around 60 months of CI use, children implanted during the sensitive period can understand speech without the aid of orofacial reading, reaching the most complex hearing abilities.

Descritores

Implante Coclear
Criança
Percepção da Fala
Perda Auditiva
Estudos Longitudinais

RESUMO

Objetivo: Verificar a influência da idade de implantação no desenvolvimento das habilidades de reconhecimento auditivo em conjunto fechado e compreensão auditiva em crianças usuárias de implante coclear unilateral, comparando grupos distintos e determinar os marcadores clínicos de desenvolvimento destas habilidades. **Método:** Participaram do estudo 180 crianças operadas e ativadas até os 36 meses de idade e que utilizaram o IC durante, no mínimo, 60 meses. Foram analisadas as habilidades de reconhecimento auditivo em conjunto fechado e compreensão auditiva por meio das Provas 5 e 6 do GASP. Para investigar a influência da idade na implantação, as crianças foram divididas em três grupos: implantadas antes dos 18 meses (G1), entre 19 e 24 meses (G2) e entre 25 e 36 meses de idade (G3). **Resultados:** Não houve diferença estatisticamente significante quando comparados os três grupos. As crianças desenvolveram progressivamente as habilidades auditivas, apresentando a habilidade de reconhecimento auditivo em conjunto fechado por volta dos 41±4 meses de uso do IC e a de compreensão auditiva por volta dos 53±4 meses. **Conclusão:** Não houve correlação entre o desempenho auditivo e a idade de implantação para as crianças implantadas antes dos 36 meses de idade. Para as habilidades de reconhecimento e compreensão auditivas, o marcador clínico foi aos 41±4 e aos 53±4 meses de idade auditiva, respectivamente. Para tanto, espera-se que, por volta dos 60 meses de uso do IC, as crianças implantadas durante o período sensível possam compreender a fala sem o auxílio da leitura orofacial, alcançando as habilidades auditivas mais complexas.

Correspondence address:
Bárbara Cristiane Sordi Silva
Rua Alameda Dr. Octávio Pinheiro Brisolla, 9/75, Jardim Brasil, Bauru (SP), Brasil, CEP: 17012-901.
E-mail: sordis@hotmail.com

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Study conducted at Hospital de Reabilitação de Anomalias Craniofaciais – HRAC, Universidade de São Paulo – USP – Bauru (SP), Brasil.

[1] Faculdade de Odontologia de Bauru – FOB, Universidade de São Paulo – USP - Bauru (SP), Brasil.

[2] Hospital de Reabilitação de Anomalias Craniofaciais – HRAC, Universidade de São Paulo – USP - Bauru (SP), Brasil.

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INTRODUCTION

Hearing loss in childhood affects the development of auditory perception of speech and language, causing negative impacts on children's communication, their interaction with the social environment and their global development. To minimize such consequences, the importance of early detection and intervention is emphasized[1-4].

Cochlear implantation (CI) is an effective alternative for the treatment of hearing loss of severe or deep degrees, especially when performed in the first years of life, as it promotes the development of auditory abilities and, consequently, favors the acquisition of language spoken[5-8]. Implantation in the first years of life allows the maturational process of the auditory cortex to occur properly as a result of electrical stimulation[5-7].

Studies that correlated auditory performance with the age of CI surgery demonstrated that children who were implanted before 12 months[9,10], 18 months[11], 24 months[12,13] and 36 months of age[14,15] presented superior auditory abilities when compared to those operated later[16,17].

However, although age is an extremely important factor, it is known that there are other variables that influence the development of auditory abilities and spoken language, such as speech therapy and family adherence to the auditory habilitation and rehabilitation process, among others[4].

Thus, it is necessary to periodically monitor children with CIs not only to make adjustments related to the programming of the electronic device, but also to check the development and rhythm of the development of auditory and linguistic abilities. To evaluate the ability of auditory speech perception in silence, there are different procedures, including the Glendonald Auditory Screening Procedure (GASP)[18,19], which has been shown to be an effective evaluation instrument for assessing the auditory performance of children with hearing loss[3,20-22].

In this context, it is important to determine the clinical markers of the development of auditory abilities in the therapeutic process, as well as the indispensability of longitudinal studies for the clinical practice, since these allow to characterize the real performance achieved by the researched population, besides evidencing the influence of different factors and the development and rate of evolution of auditory abilities and spoken language, which may differ between the implanted children[1,2,7,8,14,23]. In view of the above, the objectives of the present study were: I) To verify the influence of the age of implantation in the development of the abilities of auditory recognition in closed-set and hearing comprehension in children using an unilateral cochlear implant, comparing distinct groups and II) To determine the development markers of these abilities.

METHODS

The present is a retrospective longitudinal study, with an evaluation of the data obtained by checking the medical records of 1,214 children with CIs who are regularly enrolled in the Cochlear Implant Section of the Audiological Research Center of the Hospital for Rehabilitation of Craniofacial Anomalies of the University of São Paulo, from January 1990 to January 2015. The present work was approved by the institution's Research Ethics Committee, case number 298/2011.

Casuistry

A total of 389 children were selected based on the following inclusion criteria: having undergone surgery and the activation of the CI up to 36 months of age, with at least 60 months of use of the electronic device and being a CI user systematically, ie, without prolonged interruption of use (over three months).

Children who had at least one of the following criteria were excluded: partial insertion of the CI electrodes into the cochlea; diagnosis of malformation; reimplantation surgery in the first five years of CI use; children with associated impairments; absence in routine follow-ups; unsystematic use of the electronic device; use of bilateral CI; and children with insufficient data recorded in medical records.

After application of the eligibility criteria, the sample consisted of 180 children, divided into three distinct groups: (G1): 42 children implanted ≤ 18 months of age (mean of 15.40±2.56 months), (G2): 56 between 19 and 24 months (mean of 21.36±1.70 months) and (G3) 82 between 25 and 36 months (30.52 months±3.43).

Procedure

In order to verify the development of auditory abilities of auditory recognition in closed-set and auditory comprehension, we analyzed the GASP Tests 5 and 6, elaborated by Erber[18] and adapted to Brazilian Portuguese by Bevilacqua and Tech[19]. Test 5 assesses the ability of auditory recognition in a closed-set and is composed of monosyllable, dissyllable, trisyllable and polysyllable, totaling 12 words presented by means of figures. Test 6 examines auditory comprehension ability and is composed of ten questions previously selected. Both tests were performed in silence and the results were calculated and presented as percentage[19].

Analysis

To follow the evolution of the children in the procedures during the first 60 months of CI use, nine children's returns to the Center were determined for CI mapping, with grouping of months: 3±1 months after activation; 6±1 months; 11±1 months; 15±2 months; 22±2 months; 30±3 months; 41±4 months; 53±4 months; and 68±6 months, when considering the 180 children evaluated.

The Kruskal-Wallis test was used to compare the performance of the tests applied between the groups. The level of significance was set at 0.05.

RESULTS

The 180 children analyzed in the present study appeared in the nine follow-up returns. However, there is an inconsistency in the number of children evaluated in each of the returns. To justify such a finding, there are two possibilities: absence of the auditory abilities necessary for the execution of the tests or non-performance for any other reasons not specified in the medical records. Thus, it was not possible to perform the comparative analysis between the groups in the first two due to the reduced number of children. In this way, the analysis was performed from the third to the ninth return.

The comparative analysis of the scores obtained for closed-set auditory recognition (Test 5) and auditory comprehension (Test 6) are presented in Tables 1 and 2, respectively.

When comparing the groups' performances, both the auditory recognition in closed-set test (Table 1) and the auditory comprehension test (Table 2), there was no statistically significant difference, being p> 0.05 in all comparisons, that is, there was no influence of chronological age for the results obtained between groups G1, G2 and G3. Therefore, to determine the clinical markers of the development of these two abilities, we considered the casuistry as a whole, at each return.

Table 1. Comparative analysis for the closed-set auditory recognition ability (Test 5) between groups G1, G2 and G3, from the third to the ninth return

Return	Groups	N	Median	Average	SD	p
3	**G1**	5	50.00	51.67	25.27	0.386
	G2	18	62.50	61.11	32.41	
	G3	23	66.67	69.20	25.02	
4	**G1**	13	83.33	79.17	19.98	0.225
	G2	34	83.33	76.47	25.79	
	G3	44	70.84	65.91	30.04	
5	**G1**	31	75.00	72.99	29.05	0.366
	G2	41	100.00	81.20	28.01	
	G3	54	97.92	82.18	24.62	
6	**G1**	39	100.00	83.33	24.95	0.540
	G2	48	100.00	88.72	22.25	
	G3	68	100.00	89.52	18.93	
7	**G1**	35	100.00	95.83	9.95	0.878
	G2	51	100.00	94.45	16.53	
	G3	67	100.00	92.72	18.30	
8	**G1**	23	100.00	98.19	8.69	0.428
	G2	40	100.00	98.13	7.43	
	G3	53	100.00	95.68	14.29	
9	**G1**	42	100.00	97.02	11.43	0.161
	G2	56	100.00	99.93	0.56	
	G3	82	100.00	98.88	8.36	

Kruskal-Wallis Test
Caption: N = number of children who took the test; SD = Standard Deviation

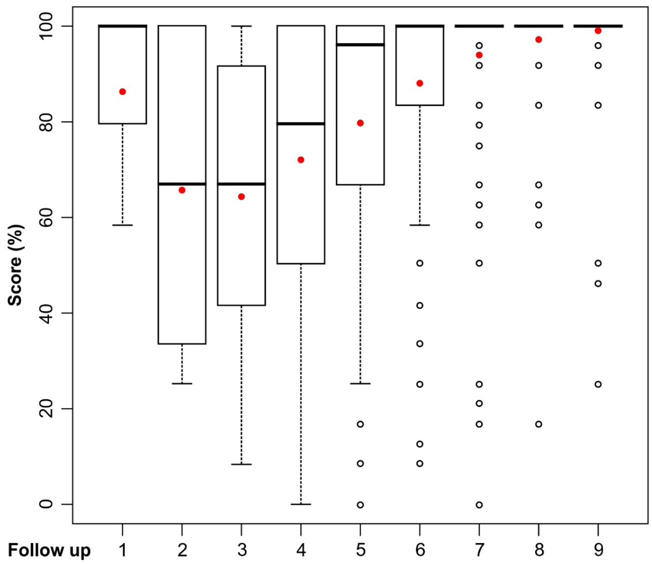
Table 2. Comparative analysis for the auditory comprehension ability (Test 6) between groups G1, G2 and G3, from the third to ninth return

Return	Groups	N	Median	Average	SD	p
3	**G1**	0	-	-	-	0.313
	G2	4	25.00	25.00	12.91	
	G3	9	50.00	45.56	33.58	
4	**G1**	7	30.00	34.29	20.70	0.963
	G2	12	35.00	36.67	21.46	
	G3	18	30.00	39.44	28.59	
5	**G1**	12	35.00	44.17	35.02	0.700
	G2	27	60.00	53.33	31.01	
	G3	27	50.00	49.63	30.32	
6	**G1**	23	80.00	69.13	30.74	0.223
	G2	37	80.00	70.81	29.57	
	G3	45	50.00	59.78	30.49	
7	**G1**	30	80.00	77.33	25.45	0.595
	G2	45	90.00	76.00	31.72	
	G3	58	80.00	71.72	29.98	
8	**G1**	21	100.00	87.62	25.48	0.094
	G2	38	100.00	88.42	21.63	
	G3	47	90.00	79.79	26.17	
9	**G1**	42	100.00	87.38	23.99	0.397
	G2	56	100.00	87.50	24.71	
	G3	82	100.00	84.76	25.86	

Kruskal-Wallis Test
Caption: N = number of children who took the test; SD = Standard Deviation

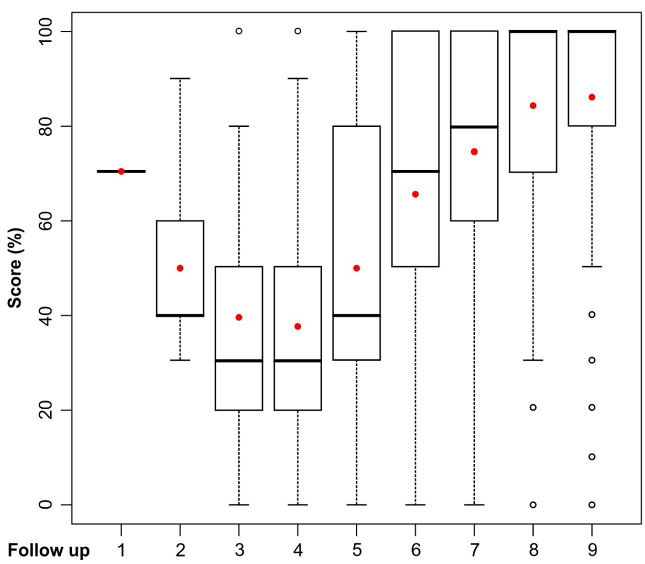
Figures 1 and 2 demonstrate the longitudinal characterization of the casuistry regarding the development of auditory recognition in closed-set (Test 5) and auditory comprehension (Test 6).

The data obtained in the present study did not follow a normal distribution, which justified the option of using the median, 1st Quartile (Q_{25}) and 3rd Quartile (Q_{75}) for the presentation of clinical markers of development. The variability of the results can be observed through the values considered as discrepant (°).



Caption: °children with deviant outcomes; Return 1 = (N=3); Return 2 = (N=16); Return 3 = (N=46); Return 4 = (N=91); Return 5 = (N=126); Return 6 = (N=155); Return 7 = (N=153); Return 8 = (N=116); Return 9 = (N=180)

Figure 1. Children's performance in the GASP Test 5, which assesses the ability of auditory recognition together closed during at least 60 months of CI use



Caption: °children with deviant outcomes; Return 1 = (N=1); Return 2 (N=6); Return 3 = (N=13); Return 4 = (N=37); Return 5 = (N=66); Return 6 (N=105); Return 7 = (N=133); Return 8 = (N=106); Return 9 (N=180)

Figure 2. Performance of children in GASP Test 6, which assesses the ability to listen for at least 60 months of CI use

From the third return (6±1 months), the performance score on the auditory ability of closed-set auditory recognition gradually increased in a larger number of children (Figure 1). In the fourth return (15±2 months), the median score was 79.17%, Q_{25} 50%, and Q_{75} 100%. At the sixth return (30±3 months), the median was observed at 100%, Q_{25} at 83.33%, and Q_{75} at 100%, and in the seventh return (41±4 months) the auditory recognition ability closed-set in silence is developed, with median in 100%, Q_{25} of 100% and Q_{75} of 100%.

In addition, it was observed in Figure 2 that, from the fourth return (15±2 months), the ability of comprehension auditory in silence began to be observed more consistently, with an increase in the performance score gradually in a greater number of children, similar to that observed in closed-set auditory recognition. In the seventh return (41±4 months), the median was observed with a score of 80%, Q_{25} of 55% and Q_{75} of 100%. The auditory comprehension ability was developed in the majority of children in the eighth return (53±4 months), median score at 100%, Q_{25} at 70% and Q_{75} at 100%.

Appendix A – Figure 1A and Appendix B - Figure 2B, graphically illustrate the clinical markers of the development of auditory recognition and comprehension abilities, respectively. The possibility of these impressions is emphasized, since they can be used in clinical practice, assisting in the auditory habilitation and rehabilitation process in children with CIs.

DISCUSSION

In the present study, 180 children were followed for auditory recognition and comprehension abilities in silence during the first five years of CI use. GASP Tests 5 and 6 were chosen because they represent the most advanced auditory abilities, ie it is assumed that speech detection and discrimination abilities have been acquired previously, so that children who achieve recognition and understanding will be suitable for verbal linguistic interactions through the auditory pathway. It should be noted that the use of GASP Tests 5 and 6 occurred in children with a chronological age of less than 60 months, although it was developed for children with profound hearing loss over five years of age, having as reference at the time it was developed in 1982 the use of individual sound amplification devices (AASI)[18,19]. It is based on the use of smaller children insofar as it is known that the CI allowed the auditory access to speech sounds soon after the activation of the electrodes, promoting the development of auditory abilities earlier.

When comparing the performances of the three groups, there was no statistically significant difference, that is, the influence of the child's age at the time of implantation in the results of GASP Tests 5 and 6 (Tables 1 and 2) was not observed. Some factors may justify this result. Initially, this could have occurred because the 180 children analyzed were implanted before 36 months, considered the sensitive period to obtain the best benefits with this device. Similar data have been reported in other studies to demonstrate that early-onset children had better auditory and oral language performance[1,7,14,24].

Sensory deprivation in the first years of life influences the maturation of the auditory pathways of the central nervous system

(CNS), with an impact on auditory processing abilities and the development of spoken language. Auditory perception consists of two types of processing: the bottom-up, which comprises sensory information, and the top-down, which encompasses aspects such as cognition, memory, language and attention[14,25].

Another factor is that although the groups performed similarly, it is noteworthy that GASP tests 5 and 6 may not be sensitive to reveal nuances in the development of auditory abilities. Therefore, the non-significance of age in surgery within the sensitive period of neuronal plasticity should not slow down the value of the age decrease in surgery. Thus, the sooner severe or profound hearing loss is diagnosed without benefits with hearing aids, the child should be given the indication of a CI, since early exposure to auditory stimuli and incidental language allows the child to have a greater chance of developing the most complex auditory abilities and spoken language. The specialized literature evidenced a strong correlation between the development of auditory function and the period of CI surgery, with sensory deprivation time and age at implantation considered as one of the main predictors of success in the auditory habilitation and rehabilitation process[5-9,26]. This is because age is an intrinsic condition for the child, which ensures the normal development of the auditory cortex, necessary for the acquisition of auditory abilities, which are prerequisites for the development of spoken language [5-9,26].

In the present study, the premise was that hearing detection, discrimination, recognition and comprehension auditory are acquired gradually, and can be interposed, according to their complexity[18]. The contribution of the present study refers to the need for markers in clinical practice, since these allow the professionals involved in the auditory habilitation and rehabilitation process to observe not only the sequence of the development of such abilities, but at what ages they occur, signaling when there is some deviant pattern, which is fundamental in the therapeutic process. Although the sequence of development of these abilities is known in children with normal hearing, systematized data in hearing loss impaired children are more scarce.

In Figures 1 and 2, it was possible to observe that in the first three months of CI use, only three children performed Test 5, and one of them was also able to perform Test 6. In the detailed analysis of the data, it was verified that one of these children presented a history of hearing loss acquisition shortly before reaching the age of three years, that is, she was not in sensory deprivation during the first two years of life, considered fundamental in the child's developmental process. In addition, two children used the hearing aid effectively and with satisfactory benefits before the implantation in the first 24 months. Certainly, the fact that these children were not in total auditory sensory deprivation in the two years prior to implantation ensured that GASP Tests 5 and 6, which require some vocabulary mastery, were performed.

In the second return, with a hearing age of approximately six months, the number of children who were able to perform Tests 5 and 6 was still incipient and, only from 11±1 months of auditory age (third return), the children manifested more ability to achieve Test 5, although this did not occur for the majority (n=46, Table 1). Concerning the auditory abilities of children with typical hearing aimed at the acquisition of oral language from birth, children process and store the linguistic repertoires to which they have access through the auditory pathway during the various communicative interactions with their parents, caregivers and others. At around nine months of age, children clearly demonstrate, through nonverbal motor behaviors, receptive language abilities since they are able to recognize and perform the motor acts corresponding to simple verbal commands such as "bye-bye", "Play kiss","clap".[27] From the age of 12 months, they can recognize their own names, body parts and vocabulary of their daily life, and from 18 to 24 months can name or name objects[27]. Thus, in the present study, considering the hearing age and not the chronological age, it was, from 11±1, that the children were able to demonstrate some receptive language ability through the auditory pathway pointing to figures corresponding to a word (Test 5), following the standard of normality for this ability. Thus, what is observed is greater variability of the results in the first year of use of the cochlear implant and, after one year of hearing age, the evolution curve of the responses is increasing and with greater regularity, as shown in Figure 1.

Although in the sixth return most of the children developed the ability of auditory recognition in closed-set at the age of 30±3 months, with median and Q_{75} of 100% and Q_{25} of 83.33%, the clinical marker to consider this established ability was the hearing age of 41±4 months, in which the ceiling effect was observed, with the exception of the deviant children.

Concerning hearing comprehension, the development of this ability was increasing over time of CI use, with greater variability in the first 12 months of auditory age, similar to auditory recognition ability. This result demonstrates the gradual development of auditory abilities according to the levels of complexity proposed by Erber[18]. The clinical marker of auditory comprehension was considered the hearing age of 53±4 months, with median and Q_{75} in 100%, and Q_{25} in 70%. It is natural that the clinical marker of this ability is at a more advanced hearing age, since understanding is the evolution of auditory recognition ability.

Figure 2 shows the evolution curve of auditory comprehension, which, although having the same increasing configuration of the auditory recognition curve, did not reach the ceiling effect with a score of 100% in the three measures analyzed in the last feedback study (68±6 months age), because in Q_{25} the score was 80%, and the score of 100% was reached only in the median and Q_{75}.

The literature reports that children with normal hearing initiate auditory comprehension ability at around 18 months[27], being able to answer simple questions related to an event, retell short stories, play songs and rhymes. Although the clinical marker of auditory comprehension is being proposed at 53±4 months, it was found that at 30±3 months of hearing age, 75% of the children had a score above 50% and a median of 70%. Considering the data presented previously for the recognition ability, the hearing age of 30 months, although not the clinical marker of ability already developed, considered when the score reaches 100%, can represent the time necessary for children to have a qualitative leap in the ascending evolution of these abilities that precede their solidification. These findings and clinical markers bring, for the field of educational audiology, more assertive perspectives for therapeutic planning consistent with the evolution profile of children. In addition, the clinical markers of the development of these abilities, for children up to 36 months of age, are 41±4 and 53±4 months of age, auditory recognition and comprehension, respectively, and, projecting these children at their chronological age, the child with the most advanced age in surgery, that is, in the present study, the one who received a CI at 35 months of age, will be 75±4 months and 87±4 months, when these abilities are solidified. The relevance of this lies in the fact that throughout this evolutionary profile the child had the possibility of acquiring oral language, reaching the period of literacy and primary education with greater chances of receptive and expressive oral language established.

In addition, the variability of the results shows that the CI satisfactorily favors many hearing loss children, but the benefits are not the same for all. As observed in Figures 1 and 2, for both abilities, some children presented deviant results. Evidence in the literature has shown that the variability of the results can be associated with innumerable factors[4,28] and, although the research presents rigid exclusion criteria for variables that could negatively influence the benefit obtained with a CI, the variability of responses is observed.

The assessment of the candidate child for a CI is multifactorial and performed by an interdisciplinary team, and covers psychosocial, audiological, clinical, anatomical aspects, access to specialized speech therapy, among others. Because it is multifactorial, the results are vulnerable to the adversity of one or associated aspects, which can lead to deviant outcomes. These findings reinforce the need for accurate guidance to the family at the time of decision for the CI as a method of auditory intervention, since, although this electronic device allows auditory access to speech sounds, there is a significant number of children that may not meet the family expectations regarding the development of spoken language[4].

Therefore, considering auditory age rather than chronological age for the analysis of these investigated abilities is fundamental, especially in family counseling, when parents yearn for immediate results as they compare their implanted children with children with normal hearing. The mismatch between the chronological age and the hearing age should be explained to the parents, decreasing the anxiety for instant results.

It is emphasized that the results found in the present study may serve as clinical markers of the development of GASP Tests 5 and 6, contributing to the process of habilitation and rehabilitation of children with a CI implanted before 36 months in order to assist in the identification of variables that positively or negatively influence the child's development (Appendix A - Figure 1A and Appendix B - Figure 2B).

It should be noted that the application of the GASP occurred in silence, which impedes the analysis of the auditory perception of speech in a broader context and that faithfully represents the daily auditory experiences that are not free of noise, which can be considered a limitation of the study. Thus, it is necessary to consider this condition when using these clinical development markers for auditory recognition and comprehension abilities.

CONCLUSION

Children progressively developed auditory abilities assessed over the first five years of CI use. There was no correlation between hearing performance and age of implantation for children implanted before 36 months of age. For auditory recognition and comprehension abilities, the clinical marker was 41±4 and 53±4 months of auditory age, respectively.

It is expected, therefore, that around 60 months of CI use, children implanted during the sensitive period of neuronal plasticity can understand speech without the aid of orofacial reading, reaching the most complex auditory abilities.

It should be emphasized that deviant results should alert professionals to the vulnerability of auditory performance due to multifactorial aspects, reinforcing care in family counseling and counseling.

REFERENCES

1. Dunn CC, Walker EA, Oleson MK, Kenworthy M, Van Voorst T, Tomblin JB. et al. Longitudinal speech perception and language performance in pediatric cochlear implant users: the effect of age at implantation. Ear Hear. 2014;35(2):148-60. http://dx.doi.org/10.1097/AUD.0b013e3182a4a8f0.
2. Ching TY, Dillon H, Day J, Crowe K, Close L, Chisholm K, et al. Early language outcomes of children with cochlear implants: interim findings of the NAL study on longitudinal outcomes of children with hearing impairment. Cochlear Implants Int. 2009;10(1, Suppl 1):28-32. http://dx.doi.org/10.1179/cim.2009.10.Supplement-1.28. PMid:19067433.
3. Almeida MG, Lewis DR. Maturação auditiva central e desenvolvimento do balbucio em crianças usuárias de implante coclear. Rev CEFAC. 2012;14(6):1096-7. http://dx.doi.org/10.1590/S1516-18462012005000006.
4. Morettin M, Santos MJD, Stefanini MR, Antonio FL, Bevilacqua MC, Cardoso MRA. Measures of quality of life in children with cochlear implant: systematic review. Braz J Otorhinolaryngol. 2013;79(3):375-90. http://dx.doi.org/10.5935/1808-8694.20130066. PMid:23743756.
5. Kappel V, Moreno ACP, Buss CH. Plasticity of the auditory system: theoretical considerations. Braz J Otorhinolaryngol. 2011;77(5):670-4. http://dx.doi.org/10.1590/S1808-86942011000500022. PMid:22030979.
6. Cardon G, Campbell J, Sharma A. Plasticity in the developing auditory cortex: evidence form children with sensorineural hearing loss an auditory neuropathy spectrum disorder. J Am Acad Audiol. 2012;23(6):396-411, quiz 495. http://dx.doi.org/10.3766/jaaa.23.6.3. PMid:22668761.
7. Kral A, Sharma A. Developmental neuroplasticity after cochlear implantation. Trends Neurosci. 2012;35(2):111-22. http://dx.doi.org/10.1016/j.tins.2011.09.004. PMid:22104561.
8. Murri A, Cuda D, Guerzoni L, Fabrizi E. Narrative abilities in early implanted children. Laryngoscope. 2015;125(7):1685-90. http://dx.doi.org/10.1002/lary.25084. PMid:25510218.
9. Dettman SJ, Pinder D, Briggs RJ, Dowell RC, Leigh JR. Communication development in children who receive the cochlear implant younger than 12 months: risks versus benefits. Ear Hear. 2007;28(2, Suppl):11S-8. http://dx.doi.org/10.1097/AUD.0b013e31803153f8. PMid:17496638.
10. May-Mederake B, Shehata-Dieler W. A case study assessing the auditory and speech development of four children implanted with cochlear implants by the chronological age of 12 months. Case Rep Otolaryngol. 2013;2013:1-10. http://dx.doi.org/10.1155/2013/359218. PMid:23509653.
11. De Raeve LA. Longitudinal study on auditory perception and speech intelligibility in deaf children implanted Young than 18 months in comparison to those implanted ate later ages. Otol Neurotol. 2010;31(8):1261-7. http://dx.doi.org/10.1097/MAO.0b013e3181f1cde3. PMid:20802371.
12. Nicholas JG, Geers AE. Will they catch up? The role of age at cochlear implantation in the spoken language development of children with severe

to profound hearing loss. J Speech Lang Hear Res. 2007;50(4):1048-62. http://dx.doi.org/10.1044/1092-4388(2007/073). PMid:17675604.

13. Miyamoto RT, Hay-Mccutcheon MJ, Iler Kirk K, Houston DM, Bergeson-Dana T. Language skills of profoundly deaf children who received cochlear implants under 12 months of age: a preliminary study. Acta Otolaryngol. 2008;128(4):373-7. http://dx.doi.org/10.1080/00016480701785012. PMid:18368568.
14. Baumgartner WD, Pok SM, Egelierler B, Franz P, Gstoettner W, Hamzavi J. The role of age in pediatric cochlear implantation. Int J Pediatr Otorhinolaryngol. 2002;62(3):223-8. http://dx.doi.org/10.1016/S0165-5876(01)00621-8. PMid:11852125.
15. Salas-Provance MB, Spencer L, Nicholas JG, Tobey E. Emergence of speech sounds between 7 and 24 months of cochlear implant use. Cochlear Implants Int. 2014;15(4):222-9. http://dx.doi.org/10.1179/1754762813Y.0000000046. PMid:24074439.
16. Geers AE, Tobey E, Moog J, Brenner C. Long-term outcomes of cochlear implantation in the preschool years: from elementary grades to high school. Int J Audiol. 2008;47(2, Suppl 2):S21-30. http://dx.doi.org/10.1080/14992020802339167. PMid:19012109.
17. Kaplan DM, Puterman M. Pediatric cochlear implants in prelingual deafness: medium and long-term outcomes. Isr Med Assoc J. 2010;12(2):107-9. PMid:20550036.
18. Erber NP. Auditory training. Alexander Graham Bell. Washington: Association for the Deaf; 1982.
19. Bevilacqua MC, Tech EA. Elaboração de um procedimento de avaliação de percepção de fala em crianças deficientes auditivas profundas a partir de cinco anos de idade. In: Marchesan IQI, Zorzi JL, Gomes, IC. Tópicos em Fonoaudiologia. São Paulo: Lovise, 1996:411-33.
20. Breneman AI, Gifford RH, Dejong MD. Cochlear implantation in children with auditory neuropathy spectrum disorder: long-term outcomes. J Am Acad Audiol. 2012;23(1):5-17. http://dx.doi.org/10.3766/jaaa.23.1.2. PMid:22284837.
21. Popov TM, Stancheva I, Kachakova DL, Rangachev J, Konov D, Varbanova S, et al. Auditory outcome after cochlear implantation in patients with congenital nonsyndromic hearing loss: influence of the GJB2 status. Otol Neurotol. 2014;35(8):1361-5. http://dx.doi.org/10.1097/MAO.0000000000000348. PMid:24691507.
22. Meneses MS, Cardoso CC, Silva IMC. Factors affecting the performance of users of cochlear implant in speech perception testing. Rev CEFAC. 2014;16(1):65-71. http://dx.doi.org/10.1590/1982-0216201411512.
23. Geers AE, Brenner CA, Tobey EA. Long-term outcomes of cochlear implantation in early childhood: sample characteristics and data collection methods. Ear Hear. 2011;32(1):2S-12. http://dx.doi.org/10.1097/AUD.0b013e3182014c53. PMid:21479156.
24. Geers AE, Nicholas JG, Sedey AL. Language skills of children with early cochlear implantation. Ear Hear. 2003;24(1, Suppl):46S-58. http://dx.doi.org/10.1097/01.AUD.0000051689.57380.1B. PMid:12612480.
25. Shuai L, Gong T. Temporal relation between top-down and bottom-up processing in lexical tone perception. Front Behav Neurosci. 2014;25(8):97. http://dx.doi.org/10.3389/fnbeh.2014.00097. PMid:24723863.
26. Nicholas JG, Geers AE. Spoken language benefits of extending cochlear implant candidacy below 12 months of age. Otol Neurotol. 2013;34(3):532-8. http://dx.doi.org/10.1097/MAO.0b013e318281e215. PMid:23478647.
27. Azevedo MF. Desenvolvimento das habilidades auditivas. In: Bevilacqua MC, Martinez MAN, Balen, SA, Pupo, AC, Reis ACMB, Frota S. Tratado de audiologia. São Paulo: Santos, 2011. p. 475-93.
28. Tanamati LF, Costa AO, Bevilacqua MC. Long-term results by using cochlear Implants on children: systematic review. Arq Int Otorrinolaringol. 2011;15(3):365-75. http://dx.doi.org/10.1590/S1809-48722011000300016.

Author contributions

BCSS and MPSC - design and delineation of the study, as well as analysis and interpretation of the data; MPSC - data collection; BCSS, ALMM, LTNS, OAC, KFA, MPSC - elaboration of the article or critical review for relevant intellectual content in addition to final approval of the version to be presented for publication.

Appendix A. Graphic illustration of the clinical marker of auditory recognition in closed-set in GASP Test 5

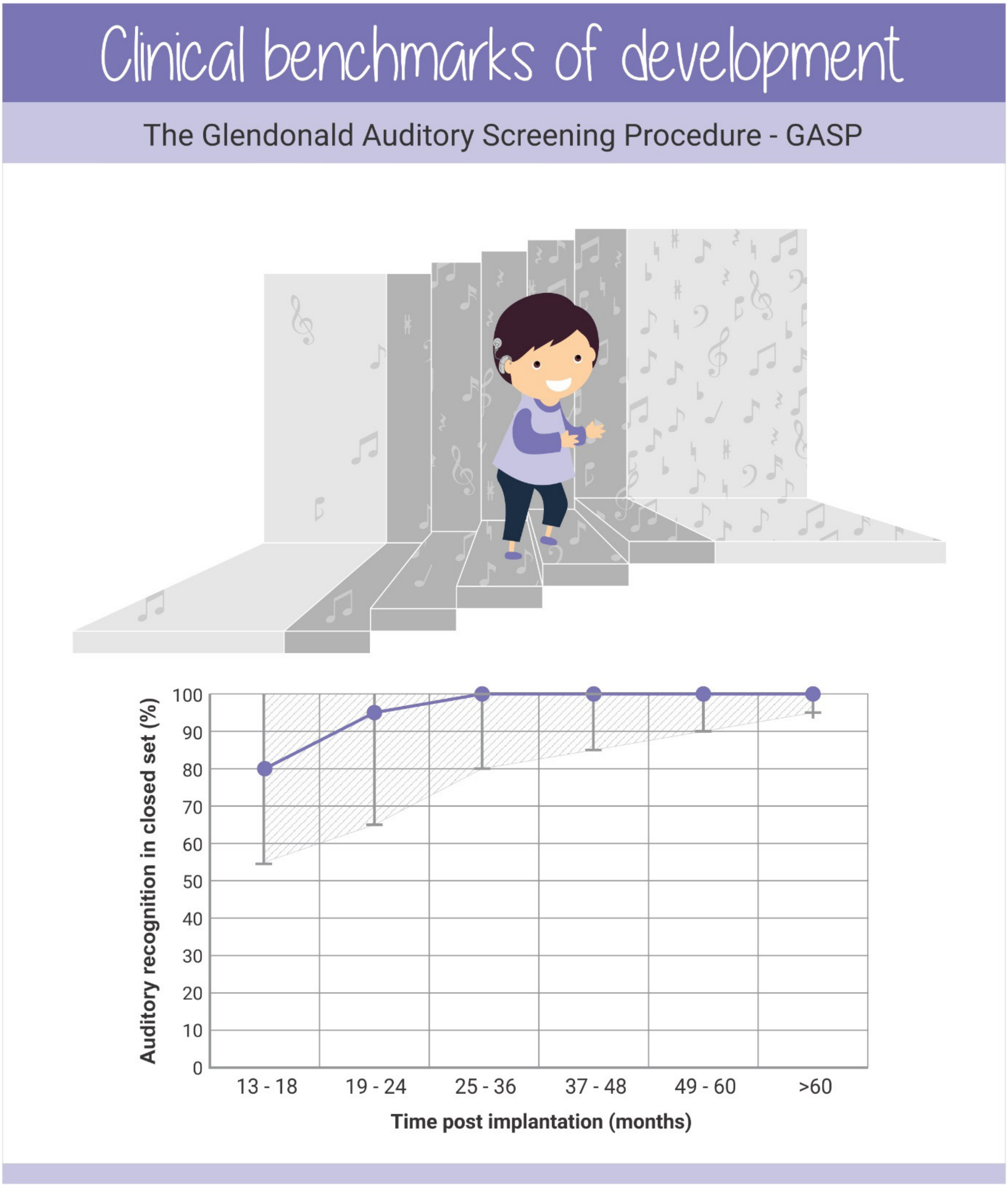


Figure 1A. Clinical marker of auditory recognition in closed-set ability in GASP Test 5

Appendix B. Graphic illustration of the clinical marker of auditory comprehension in GASP Test 6

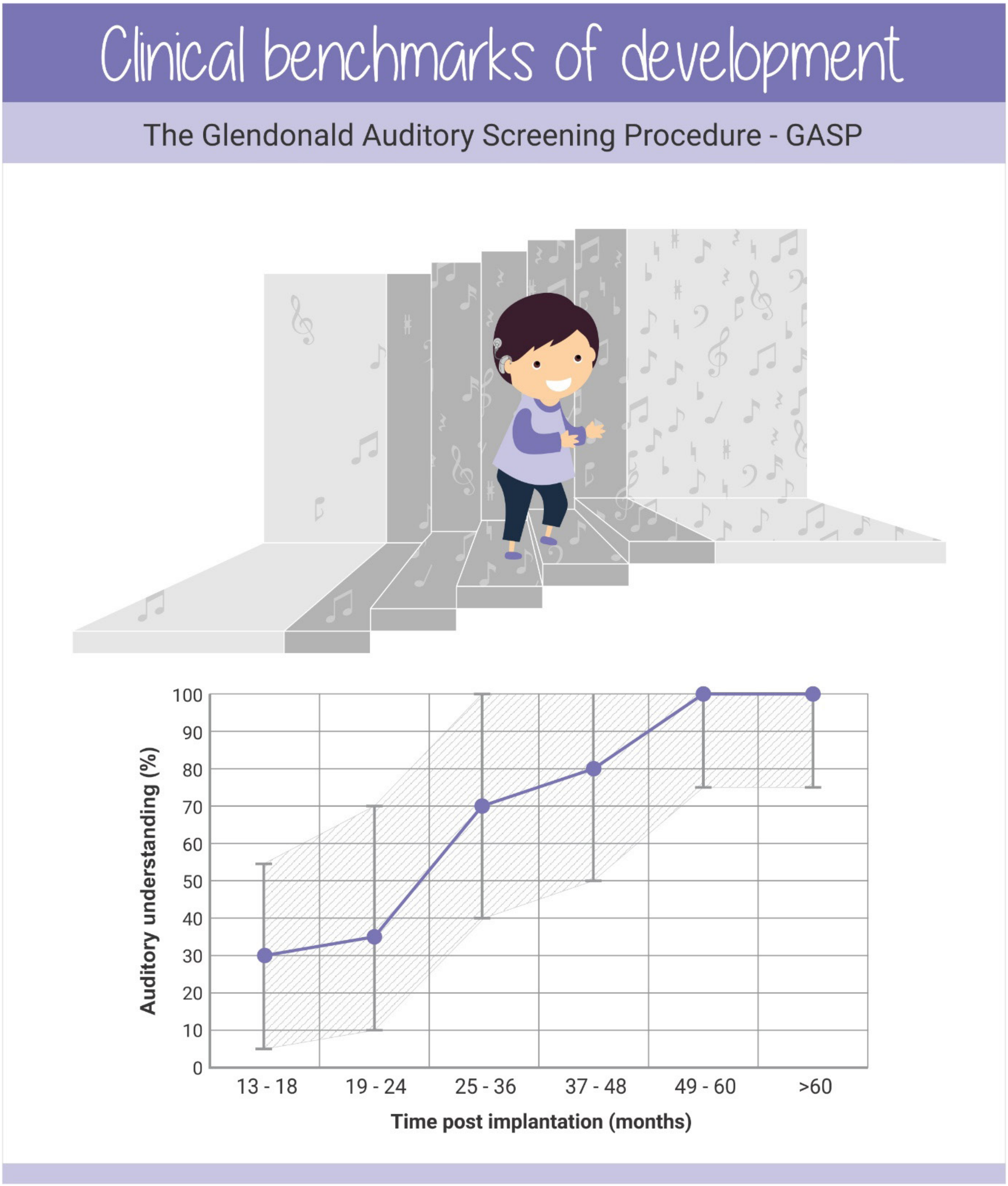


Figure 2B. Clinical marker of auditory comprehension ability in GASP Test 6