

Contribution of auditory steady state evoked potential to the election of cochlear implantation or hearing aid for children with hearing impairment

Contribuição do potencial evocado auditivo de estado estável na escolha do implante coclear ou aparelho de amplificação sonora em crianças com perda auditiva

Contribución del potencial evocado auditivo de estado estable en la elección de implantación coclear o audífono en niños con deficiencia auditiva

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Abstract

Introduction: Hearing impairment in children debilitates the acquisition and development of oral language, which can be minimized with diagnosis and confirmation of deafness in the first months of life. Auditory Steady State Evoked Potential (ASSEP) analysis stands out from others auditory evoked potentials due to the ease of recording, objectivity of the answers, stimulation of several frequencies simultaneously, in both ears, besides the identification of residual hearing. **Purpose:** Determine the contribution of the ASSEP for the therapeutic definition (election of cochlear implantation or hearing aid device) in hearing rehabilitation of children. **Methods:** The records of 20 children aged one month to three years with severe or profound bilateral neurosensory hearing loss, who were submitted to ASSEP

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Authors' contributions:

GRS: elaboration of the research, collection, analysis, interpretation and tabulation of data, final writing of the article to be published.

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and specific frequency brainstem auditory evoked potential (BAEP) analysis were analyzed. Both tests performed at frequencies of 500 Hz and 2000 Hz using the equipment Smart-EP Intelligent Hearing Systems®. **Results:** There was difference between the exams regarding the occurrence of residual hearing, since a significant number of individuals had absent responses on the BAEP and present responses on the ASSEP. There was no association between the presence of residual hearing, degree of hearing loss and the child's age with the type of therapeutic intervention. **Conclusion:** The presence of residual hearing, classification of the degree of loss and child's age exerted no influence on the final conduct.

Keywords: Auditory evoked potentials; Hearing loss; Child; Hearing.

Resumo

Introdução: A deficiência auditiva em crianças prejudica a aquisição e o desenvolvimento da linguagem oral, o que pode ser minimizado com o diagnóstico e a confirmação da surdez nos primeiros meses de vida. O Potencial Evocado auditivo de estado estável (PEAEE) destaca-se diante dos demais potenciais evocados auditivos devido à facilidade de registro, à objetividade das respostas, à estimulação de várias frequências simultaneamente, em ambas as orelhas, além da identificação da audição residual. **Objetivo:** Verificar a contribuição do PEAEE na definição terapêutica (escolha do implante coclear ou aparelho de amplificação sonora) para a reabilitação auditiva de crianças. **Método:** Foram analisados os registros de 20 crianças de um mês a três anos de idade com perda auditiva neurossensorial de grau severo ou profundo bilateral e que foram submetidas ao PEAEE e ao potencial evocado auditivo de tronco encefálico frequência específica (PEATE-FE). Ambos realizados nas frequências de 500 Hz e 2000 Hz no equipamento *Smart-EP Intelligent Hearing Systems*®. **Resultados:** Houve diferença entre os exames quanto à ocorrência de resíduo auditivo, pois, um número significativo de indivíduos apresentou respostas ausentes no PEATE-FE e respostas presentes no PEAEE. Não ocorreu associação entre a presença de resíduo auditivo, o grau da perda e a idade da criança com o tipo de intervenção terapêutica. **Conclusão:** A presença de resíduo auditivo, a classificação do grau da perda e a idade da criança não influenciaram na conduta terapêutica final.

Palavras-chave: Potenciais evocados auditivos; Perda auditiva; Criança; Audição.

Resumen

Introducción: La deficiencia auditiva en niños hace daño a la adquisición y el desarrollo del lenguaje oral, que se puede minimizar con el diagnóstico y confirmación de la sordera en los primeros meses de vida. El Potencial Evocado de Estado Estable (PEAEE) se destaca de los demás potenciales evocados auditivos por la facilidad de registro, objetividad de las respuestas, estimulación de varias frecuencias simultáneamente, en ambos oídos, además de la identificación de audición residual. **Objetivo:** Verificar la contribución del PEAEE para la definición de las terapéuticas adoptadas (elección de implantación coclear o audífono) en la rehabilitación auditiva de niños. **Método:** Fueron analizados los registros de 20 niños de un mes a tres años de edad con pérdida auditiva sensorineural de grado severo o profundo bilateral y que fueron sometidas al PEAEE y al potencial evocado auditivo de tronco encefálico por frecuencia específica (PEATE-FE). Ambos se realizaron en las frecuencias de 500 Hz y 2000 Hz en el equipo *Smart-EP Intelligent Hearing Systems*®. **Resultados:** Hubo diferencia entre los exámenes con respecto a la ocurrencia de residuo auditivo, dado que, un número significativo de sujetos presentaron respuestas ausentes en PEATE-FE y respuestas presentes en PEAEE. No hubo asociación entre la presencia de residuo auditivo, el grado de pérdida y la edad del niño con el tipo de intervención terapéutica. **Conclusión:** La presencia de residuo auditivo, clasificación del grado de pérdida y edad del niño no influyeron en la conducta final.

Palabras clave: Potenciales evocados auditivos; Pérdida auditiva; Niño; Audición.



Introduction

Hearing impairment in children impairs the acquisition and development of oral language, with a negative impact on communication and the development of cognitive skills. These damages can be minimized with the diagnosis and confirmation of deafness in the first months of life, since early diagnosis guarantees the child a shorter period of auditory deprivation and better results in the habilitation/rehabilitation process ¹.

To perform the diagnosis, electroacoustic and electrophysiological procedures are used in order to accurately determine the degree, configuration and type of hearing loss. This diagnosis should be carried out by three months of age and intervention measures by six months ².

Due to the difficulty in determining the auditory thresholds in this age group, the electrophysiological assessment is used as a resource to obtain consistent and objective responses, since it does not depend on the child's cooperation ^{3,4}.

Among these evaluation methods, the brainstem auditory evoked potentials (BAEP) with click stimulus and specific frequency stand out. In the diagnostic phase, specific frequency ABR (FEABR) is widely used to estimate the degree and configuration of hearing loss, but this assessment instrument presents limitations in the maximum stimulation output. In this way, the absence of answers suggests the presence of severe/profound hearing loss, but it is not able to differentiate them ⁵.

Currently, several studies point to the advantages of performing the steady-state auditory evoked potential (ASSR) in early audiological diagnosis. The ease of registration, the objectivity of the responses and the stimulation of several frequencies simultaneously, in both ears, are its main characteristics. However, another important aspect to be considered in the application of the ASSR is the use of stimuli at higher intensity levels than the PEATE-FE, which allows the identification of residual hearing and the determination of thresholds in severe and severe and deep hearing loss. ^{3,6}

The verification of residual hearing in children with severe - profound sensorineural hearing loss becomes increasingly important for the prognosis and determination of intervention in auditory rehabilitation, providing information for selection and adaptation of individual sound amplification

devices (AASI), as well as for the indication for cochlear implant (CI) ^{7,8}.

Because the ASSR is the main instrument capable of assessing residual hearing and considering its importance and applicability in this population ^{5,9}, it is believed that studies are essential to verify its use in diagnosis and therapeutic intervention.

From the preliminary analysis of the results found in the bibliography and the limitations identified by other methods of electrophysiological evaluation, it is believed that due to its great advantages of objective response to estimate the auditory thresholds by frequency specificity in the ears simultaneously, added to its ability to evaluate at higher intensity levels for detecting residual hearing in children, the ASSR could be an exam capable of complementing the audiological diagnosis for the early detection of hearing loss and helping to define the therapeutic approach.

Therefore, the general objective of this research was to verify the contribution of the use of the steady state auditory evoked potential as a complementary exam for the definition of therapeutic interventions adopted in the auditory habilitation/rehabilitation of children.

The specific objectives were:

1. Compare the results of the analysis of the frequencies of 500 Hz and 2000 Hz of the brainstem auditory evoked potential by specific frequency with that of the steady-state auditory evoked potential, classifying the degree of hearing loss;
2. Identify whether the type of intervention (individual sound amplification device or cochlear implant) varies depending on obtaining the auditory residues through the steady-state auditory evoked potential;
3. Verify whether the degree of hearing loss, obtained by the brainstem auditory evoked potential by specific frequency and by the steady state auditory evoked potential, interferes with the therapeutic approach;
4. Compare the indicated conducts (individual sound amplification device and cochlear implant) in relation to the age of the individuals.

Materials and methods

This study was carried out in the Audiology sector of a public institution in São Paulo. It was



approved by the Research Ethics Committee under opinion number 2,795,807, CEP number 0838/2018, CAAE 94095318.0.0000.5505 and with authorization to waive the Free and Informed Consent Form (TCLE).

The research presented a retrospective design, in which the records of the care of 20 children born at term or preterm, of both genders, who were attended in the period between 2012 and 2017 were included in the sample. bilateral sensorineural hearing loss of severe or profound degree, who were submitted to FEABR and ASSR and who presented records in medical records with complete information. Children with malformations, present otoacoustic emissions, mild or moderate conductive or sensorineural hearing loss, or with signs of neurological alteration were excluded from the sample.

FEABR recording was performed using the Smart-EP equipment, manufactured by *Intelligent Hearing Systems*®. The examination was performed in an acoustic and electrically treated room with the child in natural sleep, without the use of sedation.

To perform the exam, the skin was prepared with the aid of NuPrep™ abrasive paste. Disposable surface electrodes (*Meditrace, Kendal* brand) were positioned on the forehead (Fpz) and on the right and left mastoids (M2 and M1), following the IES 10-20 standard (*International Electrode System*). The electrode impedance was kept below 3Ω. The stimulus used was the *toneburst*, by air, at the frequencies of 500 and 2000 Hz, with ER 3 A insert earphones, with condensed polarity and application of a 30-1500 Hz filter, at least 1000 stimuli were applied, starting at intensity maximum recommended by the manufacturer (80 dBnNA), gradually reducing, every 20 dB, until wave V is no longer visible. Then, the intensity was increased 10 dB by 10 until obtaining the lowest intensity at which wave V appeared at the lowest amplitude, which is considered the electrophysiological threshold.

In the specific ABR frequencies, a threshold of 40 dBnHL for 500 Hz (with a correction factor of 15 dB) and a threshold of 30 dBnHL for 2000 Hz (with a correction factor of 5 dB) were considered normal 10.

The *Smart EP* equipment was also used to carry out the PEAE. The disposition of the electrodes and the earphone were the same used in the

PEATE-FE. The stimulation was monaural and the presentation of the stimulus was multifrequency, performed with the descending technique (10 dB).

The maximum intensity of the equipment was 117 dBNPS. The electrophysiological thresholds obtained in dBNPS were converted to dBcGNA by the equipment itself. The correction values were: -26 dB for 500 Hz, -11 dB for 1000 Hz, -13 dB for 2000 Hz and -19 dB for 4000 Hz. Comparing the amplitude of the signal and the amplitude of the noise in the presentation rate, the ASSR was automatically detected, and the response was considered present when the proportion between signal and noise was equal to or greater than 6.13 dB, with response greater than 0.0125 μV, electrical noise less than 0.5 μV and residual noise less than or equal to 0.7 μV. Statistical analysis was performed every 20 scans and the maximum presentation was 400 scans, with the application of a 30-300 Hz filter. The stimulus used was the “pip” tone, modulated at 100% in amplitude, with carrier frequencies from 500 to 4000 Hz in the modulation frequencies, in the right ear, of: 79, 87, 95, 103 Hz and, on the left ear, from: 77, 85, 93 and 101 Hz¹¹.

In the PEAE, the following was considered as a normality standard for the thresholds: 50 dBnHL at 500 Hz, 45 dBnHL at 1000 Hz, 40 dBnHL at 2000 Hz and 4000 Hz¹² and to classify the degree of hearing loss, the average of frequencies 500, 1000 and 2000 Hz was considered after obtaining the corrected threshold¹³.

Statistical analysis was performed by a qualified professional and through statistical tests consistent with the nature of the data. Descriptive analyses characterized the sample regarding the variables age, gender and therapeutic approach, presenting measures of central tendency and dispersion of the gestational age of the total sample and relative and absolute frequencies regarding the distribution of the sample in the variables sex and therapeutic approach. To compare the proportions of individuals who received the final conduct of hearing aids or CI, the binomial test was used, considering the hypothetical distribution of 50/50.

In the present study, the following were also used: *McNemar* Test, *Fisher* Exact Test and *Mann-Whitney* U Test (non-parametric). The adopted statistical significance value was equal to 5% ($p \leq 0.05$) and for the calculation of the 95% confidence intervals, the bias-corrected and accelerated method was used based on 2000 bootstrap samples.

Values in square brackets in the tables indicate the upper and lower limits of the 95% confidence intervals¹⁴.

Results

The sample consisted of 20 children with bilateral, symmetrical severe or profound sensorineural hearing loss, 12 (60%) females and eight (40%) males. The average age was 15.85 months, with a

median of 16 months, minimum age of one month and maximum of 43 months.

Indications, by a multidisciplinary team - speech therapist and otorhinolaryngologist, for adaptation of hearing aids and/or CI (bilateral) and (unilateral) were established according to Ministry of Health criteria¹⁵.

Regarding the devices indicated in the final conduct (Table 1), it was verified that these children did not differ in terms of the electronic device indicated.

Table 1. Characterization of the sample as to the final conduct, in relation to the indicated devices

Variable	Category:	Absolute frequency (n)	Relative frequency (%)	p-value
Final conduct	AASI	12	60.00	0.503
	CI:	8	40.00	
	Total	20	100	

Binomial Proportion Test

A survey of the occurrence of response in the PEATE-FE and in the ASSR was carried out in the frequencies of 500 Hz and 2000 Hz, considering the ears (Table 2). The results showed that there was a significant number of individuals who had absent responses in the PEATE-FE and present

responses in the ASSR. On the left side, there was a difference both at 500 Hz and at 2000 Hz. On the right side, a difference was found at 2000 Hz, and for the frequency of 500 Hz it was not possible to carry out this comparison due to the distribution of data that limited the use of hypothesis tests.

Table 2. Distribution of the sample results in the FE-ABR and ASSR and comparative analysis of the exams in the frequencies of 500 and 2000Hz in the right and left ear

Ear	Frequency	Exam	Result	PEAEE			p-value
				Present n (%)	Absent n (%)	Total n (%)	
Right	Total	PEATE - FE	Present	1 (5.00)	0 (0.00)	20 (100)	<0,001*
			Absent	12 (60.00)	7 (35.00)		
	500 Hz	PEATE - FE	Present	0 (0.00)	0 (0.00)	20 (100)	NC:
			Absent	7 (35.00)	13 (65.00)		
	2000 Hz	PEATE - FE	Present	1 (5.00)	0 (0.00)	20 (100)	0.004*
			Absent	9 (45.00)	10 (50.00)		
Left	Total	PEATE - FE	Present	1 (5.00)	0 (0.00)	20 (100)	<0,001*
			Absent	12 (60.00)	7 (35.00)		
	500 Hz	PEATE - FE	Present	1 (5.00)	0 (0.00)	20 (100)	0.016*
			Absent	7 (35.00)	12 (60.00)		
	2000 Hz	PEATE - FE	Present	1 (5.00)	0 (0.00)	20 (100)	0.008*
			Absent	8 (40.00)	11 (55.00)		

* Statistically significant values at the 5% level (p ≤ 0.05) - McNemar test
 Legend: NC= Not calculable due to one of the variables presenting constant behavior.

We tried to verify whether the presence of auditory residues, identified by the tests carried out, interfered with the conduct (Table 3). There was no

difference between the presence of auditory residue and the therapeutic approach, regardless of the test used in the diagnosis of hearing loss.

Table 3. Distribution of individuals and correlation analysis between the therapeutic conduct and the presence of auditory residue in each examination

Exam	Presence of hearing residue	Therapeutic conduct		p-value
		AASI n (%)	CI: n (%)	
PEATE-FE	Yes	2 (10.00)	0 (0.00)	0.147
	No	6 (30.00)	12 (60.00)	
	Total	8 (100)	12 (100)	
PEAEE	Yes	8 (40.00)	8 (40.00)	0,117
	No	0 (0.00)	4 (20.00)	
	Total	8 (100)	12 (100)	

Statistically significant values ($p \leq 0.05$) - Fisher's exact test.

Legend: AASI = individual sound amplification device; CI = cochlear implant; n = number of subjects

It was verified whether the degree of hearing loss, classified according to the results of the exams used (PEATE-FE and ASSR), did not interfere in the establishment of conducts; the data showed

that there was no association between the degree of hearing loss and the therapeutic conduct, regardless of the exam used in the diagnosis (Table 4).

Table 4. Distribution of individuals and correlation analysis between the therapeutic conduct and the degree of hearing loss in the ABR and ASSR examinations

Exam	Degree of hearing loss	Therapeutic conduct		p-value
		AASI n (%)	CI: n (%)	
PEATE-FE	Severe	2 (10.00)	0 (0.00)	0.147
	Deep	6 (30.00)	12 (60.00)	
	Total	8 (100)	12 (100)	
PEAEE	Severe	3 (15.00)	3 (15.00)	0.642
	Deep	5 (25.00)	9 (45.00)	
	Total	8 (100)	12 (100)	

Statistically significant values ($p \leq 0.05$) - Fisher's exact test.

Legend: AASI = individual sound amplification device; CI = cochlear implant; n = number of subjects

In the study, the interference of age in the choice of electronic device was not verified, and the results indicated that there was no difference between the conducts (AASI and CI) in relation

to age. Thus, children who received hearing aids were similar to those who received CI in terms of age (Table 5).

Table 5. Descriptive values and comparative analysis of age according to therapeutic conduct

Variable	Conduct	Average	SD	Median	Min.	Max.	p	T.E.
Age (months)	AASI	20.25 [13.38, 27.50]	13.80	17.50 [10.50, 31.00]	1.00	43.00	0.305	0.243
	CI:	12.92 [6.75, 19.42]	10.61	14.00 [2.50, 19.50]	1.00	28.00		

Statistically significant values ($p \leq 0.05$) - Mann-Whitney U test
 Legend: SD: Standard deviation; Min.: Minimum; Max: Maximum; T.E: Effect size.

Discussion

Considering the difficulties involved in the process of diagnosing children with hearing loss, the literature focused on child audiological assessment has suggested the use of objective procedures for early diagnosis and intervention^{3,9,16}.

In the current study, the mean age was 15.85 months. Previous research pointed to a late age in the identification of hearing loss (around 24 months), mainly in services that did not implement neonatal hearing screening¹⁷.

The recommendation of hearing health programs is that all children with hearing loss are identified before the age of three months and that intervention measures are started up to six months of age, in order to reduce the time of auditory deprivation and to guarantee the best development of auditory and language skills^{2,18,19}. Therefore, the current study demonstrated that referral for diagnosis is still carried out late.

Therapeutic intervention, soon after the diagnosis of hearing loss, is extremely important, so that the best development of the child occurs. Thus, the use of hearing aids or CI is essential. In fact, all children were referred for speech therapy qualification, most with hearing aid adaptation (Table 1). The hearing aid acts as a sound amplifier according to the degree of hearing loss. Transforms amplified sound stimuli into nerve signals, with the aim of providing the individual with the perception of sounds as close as possible to normal hearing, being able to make the remaining hair cells produce the electrical stimulus for conducting the auditory nerve. However, in some individuals the hearing aid is not able to provide the minimum satisfactory benefits. In these cases, CI is indicated, as occurred in 40% of the studied sample. Unlike hearing aids, CI electronically processes environmental sounds, transforming them into electrical impulses, which

will directly stimulate nerve endings in the auditory nerve, bypassing damaged hair cells²⁰.

After comparing the exams, in relation to the occurrence of responses in the frequencies of 500 Hz and 2000 Hz (Table 2), a higher occurrence of responses in the ASSR was observed. The higher occurrence of responses in the PEAAE is explained by the possibility of evaluation at higher intensities (up to 117 dB SPL). In PEATE-FE there is a limitation in this regard. It is performed up to 80 dBnHL, as higher intensities generate electrical artifacts in the acquisition. Such intensity is not enough for the investigation of residual hearing in children with sensorineural hearing loss^{5,7}.

In other studies, carried out with children up to six months of age with mild to profound sensorineural hearing loss^{21,22} it was possible to identify a strong correlation between the results of PEATE-FE and ASSR at the frequencies of 500 Hz and 2000 Hz, since, both exams have the ability to identify mild and moderate losses, as they have stimuli at adequate intensity. Such findings differ from those obtained in the present study, probably due to the fact that the sample is limited to severe or profound losses, in which the tests present different maximum levels of intensity.

After the diagnosis, the therapeutic approach must be established through the choice of devices (AASI or CI), in order to allow the acquisition of language in children with severe or profound sensorineural hearing loss. The results of this study did not demonstrate an association between the degree of hearing loss and the applied therapeutic approach (Table 4), as initially hypothesized. Children with profound hearing loss benefited from both the CI and the ISAD, which demonstrates the importance of the therapeutic test and the minimum experience time with this device before the indication of the CI, according to published guidelines¹⁵.

The reviewed literature emphasizes that, regardless of the degree of hearing loss, the choice

of devices for the amplification of environmental and speech sounds, whether for fitting the hearing aid or placing the CI, is important for the child to be able to develop the ability to perceive hearing loss as early as possible^{23,24}. The studies also emphasized that the therapeutic approach chosen must respect the indication criteria, considering that in profound hearing loss, the adaptation of the hearing aid presents as a limitation the reduced number of preserved hair cells, while the CI has the capacity to overcome the damaged hair cells and directly stimulate nerve fibers²⁵.

In the pediatric population, the subject of this work, establishing the diagnosis of the degree of hearing loss is a challenge for the professional speech therapist. Thus, it is recommended that both PEATE-FE and ASSR be used in the audiological assessment of children. To make such a choice, it should be taken into account that the ASSR presents the possibility of evaluating four frequencies at the same time, which makes the audiological evaluation faster. Furthermore, it reduces the risk of subjective interpretation of the results^{26,27}.

The hypothesis that the presence of auditory residue, obtained through the ASSR, would favor the use of hearing aids could not be confirmed, because even in the patient with residue, there was an indication of cochlear implant. This fact could be justified by the restricted sample size, since the ASSR has still been little used in children's audiological assessment. Thus, it is suggested that ASSR becomes more widely used, as it enables the assessment of hearing at high intensities for a better design of therapeutic intervention, also supporting that it can establish with greater precision the presence and characteristics of residual hearing in children with hearing impairment.

The literature describes some aspects for the choice of procedures and highlights the advantages of performing the ASSR in relation to the PEATE-FE. The authors explained that, for the use of PEATE-FE, each frequency must be tested individually in one ear at a time until the confirmation of the threshold, increasing the test time. In addition, in PEATE-FE, the morphology is not always clear, making it necessary to obtain several tracings to acquire responses with good reproducibility, requiring greater experience from the examiner^{26,27}. Thus, the use of ASSR would be more advantageous for: present a more objective and faster analysis of the results (especially when evaluating children

in natural sleep), evaluate several frequencies in both ears simultaneously, provide information for choosing the implanted ear, provide information for verification and validation of the device, allowing for adjustments needed^{3,5,9,26,28}.

In addition to the indication of hearing aids or CI, following the criteria established by the hearing health programs, the study sought to carry out a comparative analysis between the age of indication and the chosen conduct for auditory rehabilitation. The results demonstrated that there was no difference in the speech therapy approach in relation to age. This fact was expected since the cochlear implant must be performed between one and three years of age, for a better prognosis. In the present study, the sample ranged from one month to three years and the average age of children with indication for CI was 12.92 months, following the guidelines for hearing health²².

It is known that the cochlear implant has become an indicated treatment for children when there is no satisfactory gain with the hearing aid. CI placement at the age of one year is not recommended, as before that age there is a greater surgical and anesthetic risk. However, it is believed that their early placement is particularly important in cases of post-meningitis deafness, due to the risk of intracochlear ossification, which may prevent the placement of electrodes in the cochlea. The placement of the implant in children younger than 12 months is still controversial, with some authors defending that the audiological evaluation, surgical intervention and programming of the device in the postoperative follow-up are more difficult in this age group²⁹.

In view of the data presented above, it appears that the ASSR can be used clinically with confidence in the pediatric population to determine the degree of hearing loss. Although it is verified that this test is still not widely performed in practice, its inclusion in infant audiological diagnosis protocols is recommended due to its speed, practicality and reliability.

It is expected that more studies will be carried out with larger samples in children with disabling hearing loss, in relation to the diagnosis and definition of the therapeutic approach, in order to ensure effective early intervention.



Conclusion

The ASSR allowed checking the auditory residues, but it did not change the therapeutic approach. The presence of auditory residue, the classification of the degree of loss and the child's age did not influence the final conduct.

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