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ORIGINAL ARTICLE

Auditory and Language Outcome in Children Using Different Hearing Devices

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Abstract

Background: A delay in a child's capacity to develop language is one of the impacts of hearing loss. Children use amplification devices so they can develop spoken language skills comparable or equivalent to those of their peers without hearing loss. The aim of the study was to detect the effect of using different amplification devices on the development of the language in children.

Methods: The study included three groups of 5-8 years old children, who used different hearing devices and had bilateral severe to profound sensorineural hearing loss. Each group consisted of ten children; one using binaural hearing aids, the second had a unilateral cochlear implant, and the third group received a bimodal fitting. They were submitted to the following: history taking, intelligence and mental status examination, auditory performance assessment, and Language assessment.

Results: Bimodal and cochlear implant users have a significantly better aided response, speech understanding, and language performance than hearing aid users. There is a negative, moderate correlation between the aided hearing thresholds and treatment-related factors. Conversely, there is a positive, moderate correlation between the word recognition score, revised categories of auditory perception scale, language performance and the treatment-related factors.

Conclusions: The aided responses and language development were better among studied cases with cochlear implants and cases with bimodal hearing than cases with hearing aids. Consequently, it is crucial to assess auditory performance and language skills in each child with severe to profound hearing loss individually in terms of hearing aid benefit and the need for cochlear implantation.

Keywords: Cochlear implant; Hearing aid; Bimodal hearing; Expressive Language; Receptive Language

INTRODUCTION

Living with disabilities, such as childhood hearing loss, which is considered one of the most common disabilities, could affect academic achievement, communication with peers, and all aspects of quality of life [1]. As reported in previous studies, the prevalence of hearing loss is 1 to 3 in 1000 newborns [2,3]. Around 95% of children with hearing disabilities are born to parents with normal hearing who use spoken language to communicate. These families typically have no prior experience with hearing loss or sign language. This lack of exposure can lead parents to have high expectations for their children's spoken language skills [4].

A national hearing screening program was implemented in Egypt in 2019 to reduce the impact of hearing loss on newborns [5]. The 3rd to 7th day after delivery is recommended for newborn babies to receive hearing screenings with otoacoustic emissions. If a newborn fails the screening program, he/she should be referred to a full audiological assessment before determining the proper method for management [5].

One of the major effects of hearing loss on children is a delay in their ability to develop receptive and expressive communication skills [6]. To develop spoken language skills similar or equivalent to those of their peers with normal hearing sensitivity, amplification devices such as hearing aids (HAs) and cochlear implants (CIs) are provided to children with hearing loss. Previous studies assessed the spoken language in children amplified by HAs or CIs and concluded that amplified children had better speak language than unamplified ones [7].

Many factors can affect the development of spoken language in children using amplification, such as the type, the age of the amplification, and the duration of adequate use of the amplification device. However, there have been other factors identified as well, including higher nonverbal intelligence quotient (IQ), the absence of additional conditions or disabilities, the use of spoken language rather than sign language in rehabilitation, and higher levels of education among mothers [8].

Children with hearing loss experience large variations in their outcomes. CIs and HAs enable some children to develop age-appropriate language skills, while others have difficulty acquiring useful language skills [9]. There is a need to analyze the different effects of HAs and/or CIs on language skills development in children. Consequently, this study was designed to 1) evaluate auditory performance and language development in children using HA and/or CI and compare their outcomes and 2) investigate the effect of different factors on the development of language skills in these children.

METHODS

Ethical consideration

This research was approved by the Research Ethics Committee. Approval Code is ZU-IRB#10063/2-11-2022. Consent was obtained from all participants' parents after explaining the test procedure.

Participants

The observational, cross-sectional study was performed at the Audio-Vestibular Medicine and Phoniatric Units, ENT Department, Faculty of Medicine, Zagazig University. The study included three groups of 30 children with an age range of 5 to 8 years, of both genders, and an average IQ. They had bilateral severe to profound sensorineural hearing loss (SNHL). Their hearing loss was managed with hearing amplification devices for at least six months and received language and speech therapy (two sessions per week, every session from 20 to 25 minutes) for at least six months. Each of the three groups included ten children with Group I using binaural HAs, Group II using CI in one ear, and Group III having bimodal fitting (HA in one ear and CI in the other ear). Children with additional disabilities as neurological or systemic diseases that affect language development were excluded.

Procedure

The current study was conducted for six months from December 2022 to May 2023. All children were subjected to the following (full history taking, psychometric evaluation, otoscopic examination, auditory performance assessment (one session lasted for an hour) [basic audiological evaluation, aided hearing thresholds using warble tones, and word recognition score], and language assessment (one session lasted for an hour).

1- Full history taking: involved prenatal, perinatal, and postnatal history, past medical history for otological and neurological disorders, duration of hearing loss, type of device, duration of fitting with hearing devices, and duration of language and speech therapy.

2- Psychometric evaluation by Stanford-Binet Intelligence Scale: this test assesses IQ and cognitive abilities in children and adults aged 2 to 23 years. It tests four areas of intelligence: verbal reasoning, quantitative reasoning, abstract and visual reasoning, and short-term memory skills [10].

3- Otoscopic examination: to confirm intact external auditory canal and tympanic membrane.

4- Assessment of auditory performance:

A-Basic audiological evaluation

I) Pure-tone audiometry to confirm hearing threshold using the Orbiter 922 (GM Otomtrix Denmark). It was conducted through 1) the headphones to estimate air conduction hearing threshold at octave frequencies of 250 Hz up to 8 kHz and 2) the bone vibrator (over ipsilateral mastoid) to estimate bone conduction hearing threshold from 500 Hz to 4 kHz.

II) Speech audiometry to assess the speech perception ability of the children. It involved speech reception threshold (SRT) using Arabic spondaic words [11] and word recognition score (WRS) using Arabic phonetically balanced words [12].

III) Immittancemetry to confirm normal middle ear pressure using Amplaid 724 (Amplifon, Italy). It included tympanometry and acoustic reflex thresholds at a frequency range of 500 to 4000 Hz[13].

VI) Aided hearing threshold using warble tones to detect the aided response of the children. It was done in the sound field and estimated at a frequency range of 500 to 4000 Hz.

V) Aided speech recognition using Arabic phonetically balanced words. It was done by the examiner's live voice; the speech was introduced at an intensity of ± 40 dB SL (referenced to SRT) according to the child's tolerance and aided hearing thresholds. The child was seated in a sound-treated booth while wearing his hearing device(s), facing the speaker from which speech was introduced at one meter with zero azimuths [14]. He was asked to repeat the words, and the percentage of correct responses was calculated.

B) The Revised Categories of Auditory Perception (CAP) scale:

This scale consists of tasks that assess awareness, discrimination, identification, recognition, and auditory comprehension abilities. This could be obtained when the child responds to certain sounds, syllables, phrases, and sentences. It consists of 12 levels which reflect and monitor advanced listening skills targeted to acquisitions with implantation (level 1: unaware of environmental sounds, level 2: detects some environmental sounds, level 3: can identify some environmental sounds, level 4:understands some spoken words with additional performative, level 5: understands common phrases, level 6: understands some spoken words without additional performative, level 7: responds appropriately to simple questions, level 8: understands conversation with familiar speakers, level 9: understands conversation with unfamiliar speakers, level 10: follows recorded story, level 11: uses telephone with familiar speakers, and level: 12 uses telephone with unfamiliar speaker. This task identifies the level of auditory performance in children using hearing devices [15].

5- Language assessment by the Arabic version of the Modified Preschool Language Scale (4th edition):

The Arabic version of the Modified Preschool Language Scale (4th edition) (PLS-4) examines three scales: receptive, expressive, and total-language age, with an upper limit of language age evaluation of 83 months. This limit is the ceiling value representing the highest level of language development. The assessment involved: gesture, play, attention, vocal maturation, social interaction, vocabulary, language composition, integrative language skills, phonological awareness, and concepts. It consists of two subscales, Auditory Comprehension subscale (it contains 62 items) and Expressive Comprehension subscale (it contains 71items). The raw score of each subscale is calculated and compared to the equivalent scaled score to calculate receptive age, expressive age and total age then language quotient is calculated as follows: total language age/ chronological age, receptive language age/ chronological age and expressive language age/ chronological age. **[**16].

STATISTICAL ANALYSIS

The data were analyzed using the IBM SPSS Statistics, version 26 (IBM; Armonk, New York, USA). Categorical data were presented as numbers and percentages while quantitative data were expressed as mean ± standard deviation (SD), median, and range. The chi-square test (X^2) was used to analyze categorical variables. Quantitative data were tested for normality using Kolmogorov-Smirnova test, assuming normality at $p > 0.05$. A one-way ANOVA test was used to compare more than two quantitative variables. The post-hoc test was done to identify exactly which groups differ from each other. Pearson correlation was applied to study the association between continuous variables. The differences were considered significant at p-value ≤ 0.05.

RESULTS

The ages in the three studied groups range from 5 to 8 years, with the mean age of Group I being 7.2±0.79, Group II 7.1±1.33, and Group III 6.6±1.07 years. There is no statistically significant difference between the studied groups as regards gender distribution and IQ. The duration of speech and language therapy ranges from 3-7 years and the device administration duration ranges from 2-6 years in the three studied groups as shown in **Table 1**. The pure tone audiometry confirms the presence of bilateral severe to profound SNHL in all participants with matched SRT and WRS. Furthermore, there are statistically significant differences between the three studied groups regarding the aided response thresholds in the frequency range 1000 to 4000Hz and aided WRS with better performance in Group II and Group III than in Group I. CAP level significantly increases among Groups II and III **(Table 2)**.

Regarding language assessment, there is a statistically significant increase in PLS-4 test (expressive language and receptive language) among studied cases with CI only (Group II) and cases with CI and HA (Group III) compared to cases with HA only (Group I) as shown in **Table 3**.

Table 4 displays the effect of the treatment-related factors (the duration of language and speech therapy and device use) on the auditory and language findings in the three study groups. There is a negative, moderate correlation between the aided hearing thresholds and the treatment-related factors (the duration of language and speech therapy and device use). On the other hand, there is a positive, moderate correlation between the WRS, CAP, expressive language, receptive language, and total language and the mentioned treatment-related factors.

Table (1): Basic characteristics of the three study groups.

Patients' variables		Group I (Binaural HAs) N=10	Group II (CI) N=10	Group III (Bimodal HA & CI) N=10	Test value	*p*
Age (years)	**Mean ± SD** **Range**	7.2±0.79 6-8	7.1±1.33 5-8	6.61±1.07 5-8	0.79*	0.465 NS
Gender	**F** **M**	4 6	5 5	6 4	0.2715•	0.8731 NS
IQ	**Mean ± SD** **Range**	75 ± 3.47 70 - 79	76.8 ± 3.13 72 – 80	78.1 ± 4.79 72 -85	1.79*	0.185 NS
Duration of language and speech therapy (years)	**Mean ± SD** **Range**	5±1.49 3-7	5±1.15 4-7	4.6±0.97 3-6	0.356*	0.703 NS
Duration of using device (years)	**Mean ± SD** **Range**	4.21±1.03 3 - 6	4.22±0.42 4 - 5	3.81±1.1 2 - 5	1.51*	0.241 NS

NS: P-value (>0.05) is not significant, CI: Cochlear Implant, HA: Hearing Aid, IQ: intelligence quotient, •: x^2,* : F value

Table (2): Aided response thresholds, aided WRS and CAP among the three study groups**.**

Aided response threshold and aided WRS		Group I (Binaural HA) N= 10	Group II (CI) N=10	Group III (Bimodal HA & CI) N=10	F	*p*
Aided 500 Hz	**Mean ± SD** **Range**	38 C 7.16 30 – 45	39 ± 3.93 35 – 45	33 ± 5.37 25 - 40	3.24	0.06 NS
Aided 1000Hz	**Mean ± SD** **Range**	37 ± 4.22^{B} 35 – 45	29.1 ± 5.17 20 – 30	28 ± 5.37 20 – 35	9.88	0.001 S
Aided 2000 Hz	**Mean ± SD** **Range**	42 ± 5.37^{AB} 35 – 50	25 ± 6.67 15 – 35	25 ± 5.77 20 – 35	27.1	<0.001 HS
Aided 4000 Hz	**Mean ± SD** **Range**	35 ± 11.4^{AB} 40 – 60	27 ± 4.22 20 – 30	25 ± 3.33 20 - 30	16.4	<0.001 HS
Aided WRS%	**Mean ± SD** **Range**	25.2 ± 7.01^{AB} 16– 36	35.4 ± 7.18 28– 45	35.6 ± 5.16 28 - 45	7.84	0.002 S
CAP	Mean ± SD Range	4.4 ± 0.52^{AB} 4-5	6± 1.52 5-9	6.4 ± 1.84 4-9	5.56	0.01 S

NS: *p*-value (>0.05) is not significant, HS: *p*-value (<0.001) is highly significant, A: Significant difference between groups I and II, B: Significant difference between groups I and III, CI: Cochlear Implant, HA: Hearing Aid, CAP: The Revised Categories of Auditory Perception scale

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Table (3): PLS-4 test (Expressive, receptive, and total language scores) among the three study groups.

PLS-4 test		Group I (Binaural HA) N=10	Group II (CI) N=10	Group III (Bimodal HA & CI) N=10	F	*p*
Expressive Language age (months)	Mean ± SD Range	27.2 ± 2.44^AB^ 24 – 31	36.4 ± 3.78 33– 41	33.31 ± 4.27 26 –42	17.1	<0.001 HS
Receptive language age (months)	Mean ± SD Range	27.9 ± 4.42^AB^ 22 – 33	39.5 ± 4.48 33– 44	35.7 ± 6.36 26 – 44	12.6	<0.001 HS
Total language age (months)	Mean ± SD Range	28.9 ± 3.51^AB^ 22– 33	36.2 ± 2.53 33– 39	34.6 ± 2.73 31– 39	16.6	<0.001 HS

Abbreviations: HS: P-value<0.001 is high significant, A: Significant difference between groups I and II, B: Significant difference between groups I and III , CI: Cochlear Implant, HA: Hearing Aid

Table (4): Correlation between treatment-related factors (the duration of language and speech therapy and device use) and the auditory and language outcomes in the three study groups.

Auditory and language outcomes		Duration of Language and Speech Therapy			Duration of device use		
		Group I	Group II	Group III	Group I	Group II	Group III
Aided500 Hz	*r*	-0.444	-0.314	-0.302	-0.423	-.0.500	-0.421
	p	0.014	0.012	0.016	0.014	0.005	0.003
Aided1000 Hz	*r*	-0.338	-0.325	-0.453	-0.456	-0.392	-0.357
	p	0.068	0.054	0.043	0.067	0.117	0.123
Aided2000 Hz	*r*	-0.366	-0. 346	-0.445	-0.578	-0.428	-0.423
	p	0.381	0.371	0.245	0.248	0.226	0.456
Aided4000 Hz	*r*	-0.496	-0.563	-0.356	-0.445	-0.301	-0.611
	p	0.300	0.342	0.542	0.034	0.212	0.156
WRS %	*r*	0.466	0.432	0.564	0.543	0.505	0.467
	p	0.008	0.004	0.0125	0.004	0.003	0.157
CAP	*r*	0.480	0.453	0.543	0.577	0.676	0.634
	p	0.007	0.004	0.052	0.006	0.001	0.045
Expressive language	*r*	0.501	0.546	0.589	0.345	0.415	0.654
	p	0.008	0.007	0.023	0.045	0.039	0.067
Receptive language	*r*	0.343	0.347	0.452	0.378	0.526	0.445
	p	0.020	0.054	0.046	0.001	0.002	0.080
Total language	*r*	0.513	0.546	0.469	0.345	0.497	0.544
	p	0.006	0.004	0.050	0.047	0.009	0.098

WRS: Word Recognition Score**,** CAP: The Revised Categories of Auditory Perception scale.

DISCUSSION

This research described the auditory performance and language development among groups of children using different hearing devices (binaural HAs, unilateral CI, and bimodal hearing). Also, this study investigated treatment-related factors

that could impact language development, such as the duration of speech and language therapy, and the duration of using these amplification devices.
To study the auditory performance and language development in children using binaural HAs, unilateral CIs, and bimodal hearing, it was essential to select the three groups with the same basic characteristics including age, gender, IQ, duration of language and speech therapy, and duration of using the amplification devices **(Table 1)**.

Regarding auditory performance, the present study showed better-aided response thresholds at 1000, 2000, and 4000 Hz and aided WRS in groups II and III than the group I **(Table 2)**. Potts et al. [17] found an improvement of auditory performance in the adult using bimodal condition than adult using CI on one side and those using binaural HAs. In addition, they discovered that bimodal users had considerably higher word scores than CI-only users [17].

HAs in bimodal hearing offer a crucial benefit: they pick up low-frequency sounds that CI cannot perform. This improves speech recognition in both quiet and noisy environments. Having this low-frequency information alongside the CI signal also leads to better sound quality [17].

Furthermore, the current study revealed a significant improvement in auditory performance (CAP test) in children with CIs (Group II) and in children with bimodal hearing (Group III) compared with HAs (Group I) **(Table 2)**. This result follows another study, which compared CAP test in children using HAs and CIs and revealed higher auditory performance and for CIs as compared to that for HAs [١8]. It was noticed that the CI children performed much better than children using HAs in the acquisition of language. This supports the present study that the CIs provide greater performance than HAs [19].

The expressive and receptive language among the studied groups was better in cases with CI only (Group II) and with CI and HA (Group III) compared to cases with HA only (Group I) **(Table 3)**.These results are consistent with **Sininger et al. [**20] who examined 16 children fitted with mainly unilateral CIs at the median age of 28.5 months, while 28 children with mild-to-profound HL continued to use HAs. They found that CI use was associated with better speech perception, speech production, and language outcomes in preschool-aged children with hearing loss than in children who continue HAs.

Additionally, this is matched with some studies that have sought to compare the spoken language profiles of children with mild-to-profound HL who received HAs to those of children who received CIs [21]. Similarly, a good performance was noticed for children utilizing bilateral devices, either bilateral CIs or bimodal devices [٢2]. This study examined the receptive language and vocabulary of 117 children, aged 4.8–9.4 years. On average, these participants exhibited receptive language and vocabulary skills within the normative range for typically developing children [23].

Moreover, the current findings agreed with other studies conducted on CI recipients. These studies found that for children with hearing loss in the severe range in at least one ear, a combination of HA and CI use for an extended time (approximately 3–4 years) facilitated better receptive language and vocabulary than was found for children who had discontinued HA use by receiving a second CI [24]. On the other hand, **Fitzpatrick et al.** [٢5] reported significant differences in language skills between children with severe to profound hearing loss who used CIs or HAs at 4 to 5 years of age. These results could be explained by the fact that young children who experienced severe to profound SNHL struggle to develop spoken language regardless of amplification (HAs or CIs) due to the difficulty of detecting acoustic-phonetic cues that were essential for speech recognition [26].

For children with severe to profound hearing loss, CIs offer a clearer advantage in understanding and speaking spoken language compared to HAs [27]. While HAs might not amplify sound enough for these children, they can still be helpful in certain ways. They provide the benefit of hearing with bimodal stimulation, which can be advantageous. HAs typically work well for low frequency sounds. This can complement CIs, especially if the implant's electrode is short or not inserted perfectly. This is because the part of the ear responsible for lower-pitched sounds is located near the tip of the cochlea. By filling this gap and covering the entire range of speech frequencies, HAs can contribute to better language development for children [28]. Children who use either bilateral CIs or bimodal stimulation can benefit from improved sound localization and speech understanding in both quiet and noisy environments [29-30].

Treatment-related factors such as the duration of speech and language therapy and the duration of using these devices could impact language development. Therefore, they have been examined in the current study. A negative, moderate association was found between the aided hearing thresholds and the treatment-related factors in the three groups. On the other hand, there was a positive, moderate association between the WRS, CAP, expressive language, receptive language, and total language and the treatment-related factors in the three groups **(Table 4)**.

The current study aligns with previous research by comparing language development in different domains for children who received CIs. The average age of the children was 4.7 years old. The earlier research found that children who received speech therapy for at least two years after implantation scored significantly better on all language tests compared to those who received therapy for one year or less. This confirms that extended therapy following cochlear implantation is crucial for children to learn and process sounds, ultimately improving their language abilities. While the age of implantation (before or after 3 years) didn't significantly affect language development in this study [31]. Similar to other research, it confirms that longer therapy after implantation leads to better language outcomes. This highlights the importance of proper speech and auditory therapy following cochlear implantation to improve hearing and communication skills [32].

Limitations

Studies have shown that CIs enhance both sound localization and speech understanding in noisy environments. Additionally, children with bilateral CIs tend to develop spoken language skills more effectively compared to those with unilateral CIs. Thus, further research is needed to evaluate receptive and expressive language skills for SNHL children with different devices (binaural HAs fitting, unilateral CIs, bimodal hearing, and bilateral CIs). Thus, we need more knowledge on the spoken-language skills of children with profound hearing loss who have undergone early bilateral implantation and of children with mild-to-severe hearing loss with early bilateral HA fitting. Another limitation of this study was the relatively small sample size, and the challenges associated with recruiting a larger number of children.

CONCLUSION

Bimodal (CI + HA) and CI users showed better aided response and speech understanding than HA users. Also, there was better expressive and receptive language among children with CIs only and those with CIs and HAs than children with HAs only. Overall, every child with severe to profound hearing loss needs individualized assessments for HA benefit, cochlear implantation potential, and speech-language therapy outcomes. This could be crucial if there are concerns about the effectiveness of HAs, the amount or quality of language used at home, or delays in spoken language development.

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