Auditory Perception and Verbal Intelligibility in Children with Cochlear Implant, Hearing Aids and Normal Hearing

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ABSTRACT

Objective: The aim of the present research was to compare the auditory perception and verbal intelligibility in children with cochlear implant, hearing aids and normal hearing.

Methods: 60 children aged 5-7 years were divided to three groups and each group contained 20 children. The first and second groups were selected ordinarily from children with cochlear implant and hearing aids by convenient sampling method, while that third group was selected randomly from children with normal hearing. All participants answered to Categories of Auditory Performance (CAP) and Speech Intelligibility Rating (SIR).

Results: The results revealed that mean scores of CAP and SIR in normal hearing children were significantly higher than the mean scores of children in other groups ($P<0.0005$). In addition, the mean scores of CAP in children with cochlear implant were significantly more than the mean scores of children with hearing aids ($P<0.002$); also, the mean scores of SIR in children with cochlear implant had not a significant difference in children with hearing aids ($P<0.65$).

Conclusion: This study confirms that auditory perception and verbal intelligibility are multidimensional and complex phenomenon. They require unique rehabilitation program in order to achieve more development in speech skills.

1. Introduction

Within the past 25 years, physicians have been able to offer severely and profoundly deaf people an opportunity to regain at least partial auditory function through the cochlear implant. While, hearing aids only amplify sound and deliver it to a damage auditory system and children with hearing aids receive louder sounds there is not still valid information, indicating that cochlear implant can provide better speech understanding (Hodges & Balkany, 2002).

The cochlear implantation program was done in Iran in 1991 and has developed rapidly (Daneshi & Hasanzadeh, 2007). Cochlear implantation is an accepted treatment method for children with a bilateral severe-profound sensory neural hearing loss, and is accessible to many children across the globe (Phillips et al., 2009). It is now well documented that children with profound hearing loss benefit from cochlear implant in terms of speech perception and language development (Geers et al., 2008; Nicholas & Geers, 2007) The risk of serious speech and language delays that can impact communication, academic, and social development are more in children with profound sensory neural hearing loss (Holt, 1994).

More recent studies of children implanted at younger ages using new technologies report better auditory perception abilities, while it has been suggested that, the children with cochlear implant perform at a level equivalent to children

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with severe hearing loss who are using hearing aids (Blamey et al., 2001; Sarant, 2012). It has recently been reported that very young children can perform on auditory perception tests at a level equivalent to children with a moderate hearing loss who are using hearing aids (Leigh et al., 2008).

Cochlear implant has been associated with stronger outcomes in auditory perception (Tyler et al., 2001), speech production (Connor et al., 2000; Geers, 2002), language (Svirsky, 2001), and reading (Geers, 2002; Connor & Zwolan, 2004) compared to children using conventional hearing aids. However, the variability in these results are more frequent, and many factors seem to contribute to the successful application of cochlear implant. In particular, the age at which children receive a cochlear implant has been related to auditory perception, speech, language, and literacy outcomes (Connor & Zwolan, 2004; Lederber & Spencer, 2005; Tomblin et al., 2005).

The development of auditory perception has always been a significant problem for children with severe-profound hearing loss, as they do not have the auditory capacity to monitor their own speech or to hear the speech of normal hearing individuals. For many years, most children using hearing aids with this degree of hearing loss have been rated as unintelligible, or as having very low intelligibility (Spencer et al., 2011). Cochlear implant can provide children new auditory information and make them able to have their own speech, so that they can learn from speakers with normal hearing, and monitor their own speech production.

Children with cochlear implant show a wide range of speech production abilities. Some of them perform at high level, while others show low levels of performance in auditory perception (Connor et al., 2006; Spencer et al., 2008). Children implanted at relatively late ages and with only a few years of implant utilization are generally rated as much more auditory perception and speech intelligible as their peers with a similar degree of hearing loss using hearing aids (Connor et al., 2006; Flipsen, 2008). Although for many children, they are still not equivalent to those of children with normal hearing, auditory perception outcomes have improved over time because of longer periods of implant experience and improved hardware and speech processing strategies. (Chin, 2003; Peng et al., 2004).

Speech production skills and speech intelligibility ratings equivalent to those of 'gold' hearing aid users have been reported less than 3 years after implementation (Blamey et al., 2006; Svirsky et al., 2000). Children who are implanted at younger ages and use more recent technology demonstrate the greatest achievements with intelligibility ratings of 60-75% and much higher rates of speech production accuracy reported (Peng et al., 2004; Ertmer et al., 2007; Flipsen., 2008).

One of the most challenging findings of research on speech perception and speech production ability in children with cochlear implant is the enormous variation in performance between individuals (Pyman et al., 2000; Sarant et al., 2001). Many reports describe 'average' performance. In fact, while some children do reasonably well, there are still children who derive very little benefit from their cochlear implant. This variation in outcomes makes it difficult to predict how a particular child will perform after implantation. Therefore, it seems necessary to determine which children are suitable for a cochlear implant, particularly in children with sensible residual hearing (Sarant, 2012).

Although many studies compared auditory perception and verbal intelligibility in children with cochlear implant, hearing aids and normal hearing, assessment tools in many studies were language and age-dependent and demonstrate a low validity and reliability. There is not enough documented data and we still encounter difficulties in performing efficacy as well as limited statistical supports and greater inner-subject variances. Two language-independent assessment scales are available to assess speech perception and speech production: The Categories of Auditory Performance (CAP) (Archbold et al., 1995) assesses auditory perception, which is the awareness, recognition and interpretation of auditory stimuli received in the brain (Stach, 1997).

The Speech Intelligibility Rating (SIR) (Allen, 1986) assesses verbal intelligibility, which is the degree to which a speaker has intended other listeners (Archbold et al., 1998) can recover message. The validity, reliability and inter-tester reliability are well documented in research for both assessment measures (Allen, 1986; Archbold et al., 1998). Both measures can be used pre and post operatively and are age-independent and easy to translate.

This study aimed to compare auditory perception and verbal intelligibility in children with cochlear implant, hearing aids and normal hearing.

2. Methods

In descriptive-analytic and comparative research, 60 male children aged 5-7 years from Pishva, Gharchak and Pakdasht districts were participated. Ethics committee of exceptional education organization in Iran approved this study. The importance of research was explained to the principals, counselors and parents of participants, ensuring that all participants would be protected against any probable harm. Informed consent was also obtained from parents of participants.

All children were divided into three groups and each group consisted of 20 children. First and second groups that suffered from sensory-neural in both ears were selected by convenient sampling method from children with cochlear implant and the people in waiting list for the ear hearing aids while the third group was selected randomly from children with normal hearing. The children in first and second group were prelingually deaf. Children with cochlear implant have severe-profound hearing loss (range of higher than 70 dB) and children with hearing aids have mild-moderate hearing loss (range of from 35 to 69 dB). Children with cochlear implant and hearing aids have been using prosthesis from 2 to 5 years old ages with mean of age 3.8 & 4.1 years, ordinarily. All of the participants were Persian native speakers and had no confirmed diseases or neurological disorders. They were matched with each other in IQ, age and gender.

Measures

Leiter International Performance Scale-Revised

This scale was used to assess intelligence, attention deficit/hyperactivity disorder and learning disability. This scale is a nonverbal revised Leiter originally designed for deaf persons but often used with patients who cannot communicate verbally. The scale consists of two components: (1) visualization and reasoning domains for measuring intelligence quotient, and (2) attention and memory domains to distinguish children with attention deficit/hyperactivity disorder, learning disability or neuropsychological impairment. The reliability of this test, based on internal consistency (Cronbach's Alpha) and test-retest, is 0.83 and 0.85, respectively. The concurrent validity using Wechsler's Intelligence Scale for Children, The Third Revision (WISC-III) (in the attention composite of which the attention sustain is one of two subtests) is 0.83.7 (Roid & Miller, 1997).

Category of Auditory Performance (CAP)

The CAP quantifies the auditory receptive abilities of linguistically compromised profoundly deaf children in a clinical setting. The CAP is an eight-point rating scale ranging from 'displays no awareness of environmental sounds' to 'can use a telephone with a familiar talker. The validity, reliability and inter-tester reliability are well documented in research (Allen, 1986; Archbold et al., 1998).

Speech Intelligibility Rating (SIR)

The SIR quantifies the verbal intelligibility abilities of deaf children in a clinical setting. The SIR is a five-point rating scale ranging from 'pre-recognizable words in spoken language to 'connected speech intelligible to all listeners'. The reliability of this scale has been evaluated, and a high rate of agreement found between observers using the scale to assess the speech intelligibility of deaf children after cochlear implant. A speech therapist rated each child's performance according to the scale, as directed by predefined guidelines, and suggested by the authors of the scale (Allen, 1986).

Participants were assessed with revised Leiter intelligence scale, CAP and SIR, at the time of gathering data. Data were presented as means and standard deviations. ANOVA were used in order to detect significant differences between IQ and age of three groups. The auditory perception and verbal intelligibility in children with cochlear implant were compared with those of children with hearing aids and normal hearing. MANOVA were applied in order to detect significant differences among children with cochlear implant, hearing aids and normal hearing. SPSS version 16.0 was used for statistical analysis.

3. Results

There were no significant differences among children with cochlear implant, hearing aids and normal hearing in terms of age ($F=0.95$, $P<0.29$) and IQ ($F=1.20$, $P<0.54$). Mean scores and standard deviation of auditory perception and verbal intelligibility in three groups are shown in Table 1.

In order to compare the mean scores of auditory perception and verbal intelligibility in groups, MANOVA was used. At first, the equality of variances was confirmed by with Leven test (Table 2). Also, the equal-

Table 1. Mean and standard deviation of CAP and SIR in three groups.

Variables	C CI		C HA		C NH	
	Mean	SD	Mean	SD	Mean	SD
Auditory perception	6.95	1.27	5.75	1.11	8.75	0.55
Verbal intelligibility	3.35	0.48	3.10	0.78	4.85	0.48

C CI=Children with Cochlear Implant C HA=Children with Hearing Aids
C NH=Children with Normal Hearing

Table 2. Leven test for equality of variances.

Variables	F	df_1	df_2	P
Auditory perception	2.39	2	57	0.10
Verbal intelligibility	2.52	2	57	0.08

(n=60)

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ity of variance-covariance matrix assumption was confirmed by Box test (P=0.07).

To compare the total mean scores of auditory perception and verbal intelligibility in groups MANOVA was used. The overall Wilk's lambda was significant, ($F_{(4,112)}$=31.40, P<0.0005), indicating overall differentiation of three groups. MANOVA was used in order to understand the differences among the mean scores of auditory perception and verbal intelligibility in groups (Table 3).

As can be observed (Table 3), there were significant differences in mean scores of auditory perception (F=42.99, P<0.0005) and verbal intelligibility (F=45.59, P<0.0005) in groups. Furthermore, to compare the mean scores of auditory perception to verbal intelligibility in three groups a Bonferroni post hoc test was used (Table 4).

As can be observed (Table 4), the results of Bonferroni post hoc test revealed that mean scores of auditory perception and verbal intelligibility in normal hearing children were significantly more than children in other groups (P<0.0005). Also, mean scores of auditory perception in children with cochlear implant were significantly higher than children with hearing aids (P<0.002); while mean scores of verbal intelligibility in children with cochlear implant did not have a significant difference with hearing aids children (P<0.65).

4. Discussion

The aim of the study was to compare auditory perception and verbal intelligibility in children with cochlear implant, hearing aids and normal hearing in Tehran provinces. The results of MANOVA showed a significant difference in mean scores of auditory perception and verbal intelligibility in groups. Bonferroni post hoc test revealed that mean scores of auditory perception and verbal intelligibility scores in normal hearing children were significantly more than equivalent group. This result was similar to study of Kord et al. (2005), Peng et al. (2008) and Khalesi et al. (2001) that concluded, "the mean scores of auditory perception and verbal intelligibility in normal hearing children were significantly more than the mean scores of children with cochlear implant". In addition, this result was consistent with the study of Lee et al. (2002) that concluded, "auditory perceptions in children with cochlear implant were significantly lower than children with normal hearing". It indicates that comparing children with more hearing experience to those with lower hearing experience, the second group posses better results.

Hearing impairment especially auditory perception and verbal intelligibility affects all aspects of life. On the other hand, the development of auditory perception and verbal intelligibility have always been a significant problem for children with severe-profound hearing loss, as they do not have the auditory capacity to monitor their own speech or to hear the speech of normal-hearing individuals (Spencer et al., 2011).

Another finding of present study indicated that the mean scores of auditory perception in children with cochlear implant were significantly more than the scores of children with hearing aids. This finding was similar to study result of Tyler et al. (2001), Blamey et al. (2006) and Meyer et al. (1998) that concluded, "the mean scores of auditory perception in children with cochlear implant were significantly less affected". In addition, this finding was in concordance with result of Ghasemei et al. (2006) that found cochlear implant would have more effectiveness on the auditory perception in the children with severe-profound hearing impairment.

Table 3. Results of MANOVA in three groups.

Variables	SS	df	MS	F	P	η^2
Auditory perception	91.20	2	45.60	42.99	<0.0005	0.60
Verbal intelligibility	35.83	2	17.91	45.59	<0.0005	0.61

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Table 4. Results of bonferroni post hoc test in three groups.

Variables	Groups	Comparisons	Mean difference	P
Auditory perception	C NH	C CI	1.80	<0.0005
		C HI	3.00	<0.0005
	C CI	C HA	1.20	<0.002
Verbal intelligibility	C NH	C CI	1.50	<0.0005
		C HA	1.70	<0.0005
	C CI	C HA	0.25	<0.65

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The findings are not so surprising because it concludes that the difference in auditory perception is due to greater benefits that children with severe-profound hearing loss gain from cochlear implantation (Geers et al., 2008; Nicholas & Geers, 2007). Because cochlear implant technology optimizes pitch encoding and auditory perception abilities them, one can expect that auditory perception in children with cochlear implant acquired better results. On the other hand, cochlear implant can provide auditory information that improves auditory perception users so that they can learn from speakers with normal hearing, and monitor their own speech production and receive feedback (Connor et al., 2006; Spencer et al., 2008).

The final finding of this research showed that mean scores of verbal intelligibility in children with cochlear implant had not a significant difference with hearing aids children. This result was similar to result of Most & Peled (2007) which concluded, "perception of supra segmental features of speech in children with cochlear implant had not a significant effect on children with hearing aids". In addition, this result was similar to result of Mahmoudi et al. (2009) suggesting that voice abnormalities in speech of children with cochlear implant had not a significant difference with children with hearing aids. This final finding was not similar with study result of Tyler et al. (2001) that concluded use of a cochlear implant has been associated with stronger outcomes in speech production and verbal intelligibility compared with children using conventional hearing aids.

For explanation this controversial result, it is clear that a properly functioning cochlear implant does not guarantee this outcome (Dowell et al., 1995; Miyamoto et al., 1994). Therefore, it can be inferred that sometimes children with cochlear implant perform at a level in comparison to those children with a severe hearing loss (Blamey et al., 2001). It has recently been reported that young children can perform better than their counterparts with moderate hearing loss in verbal intelligibility test (Leigh et al., 2008).

The variability in these results among children is high, and many factors seem to contribute to the successful use of cochlear implant. In particular, type and rate of hearing impairment, use of rehabilitation program and the age at which children receive a cochlear implant has been related to verbal intelligibility outcomes (Connor & Zwolan, 2004; Lederber & Spencer, 2005; Tomblin et al., 2005; Hasanzadeh, 2012).

It is important to mention several limitations of the study. First, the sample size for three groups of children was relatively small. Analyses with these small sample sizes should be interpreted conservatively. Second, only male gender in Tehran provinces participated in this study. These limitations made it difficult to generalize the findings of the study to the other population. One of the most challenging findings of research on auditory perception and verbal intelligibility ability in children with cochlear implant and hearing aids is the enormous variation in performance between individuals.

This study created numerous recommendations for further research. First, it is recommended that paying attention to deafness of students' parents, personality characteristics, and deafness level of the students can provide more detailed results, which are beneficial for compare of auditory perception and verbal intelligibility in deaf children. Second, since auditory perception and verbal intelligibility are multidimensional and complex phenomenon, they require unique rehabilitation program in order to achieve more development in speech skill of children with cochlear implant or hearing aids. Therefore, regarding psychological problems related to auditory perception and verbal intelligibility of deaf children, it is valuable to develop and plan programs, which are aimed at improving speech skills in affected children.

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