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Comparison of IQ between 4-16 year-old children after cochlear implantation in the left or right ear

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Abstract

Purpose: Hemispheric dominance is associated with more activity in one half of the body, which is very important in the presence of a relationship between the intelligence and brain lateralization. Delayed language development in the children undergoing cochlear implantation can have deleterious effects on their growth, academic performance, adaptation, and social interactions. Regarding this, the present study aimed to determine the relationship between the dominant hand and intelligence in the 4-16 year-old children undergoing cochlear implantation in the left or right ear.

Methods: This cross-sectional study was conducted on the records of the patients aged within 4-16 years who had undergone cochlear implantation during 20082011. The subjects' IQ was measured using Wechsler test by a neuroscience specialist. Then, the IQ of the children with the right cochlear implant was compared to that of those with left implant. The data were analyzed using the ttest, Fisher's exact test, Mann-Whitney U test, and Chi-square test in SPSS version 18.

Results: According to the results, there was no significant difference between the children with right and left cochlear implants in terms of the mean IQ score (P=0.54). Furthermore, no significant association was observed between IQ score and right-handedness or left-handedness in the children undergoing cochlear implantation (P=0.17, P=0.8, respectively).

Conclusion: As the findings indicated, there was no relationship between the dominant hand and IQ score in the children undergoing cochlear implantation.
Key words: *Brain hemisphere, Cochlear implantation, IQ, Predominant hand*

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Introduction

Until decades ago, there was no solution for congenital deafness, and most of the patients inflicted with this disorder had to remain deaf for lifelong. However, the advancements of technology led to the innovation of hearing prosthetics, which have been helpful in this regard. Annually, one case per 1,000 neonates is born with hearing impairment [1], and Iran is no exception in this respect [2].

Cochlear implantation is one of the best treatment methods for the people with severe and profound hearing loss. The implanted cochlea is a prosthetic device that is inserted in the inner ear through surgery. This device stimulates the auditory nerve fibers to excite the acoustic sensation in the person with severe and deep sensorineural hearing loss [3]. Cochlear implantation facilitates the removal of damaged hair cells and direct stimulation of the auditory nerve [4].

Currently, there is a high tendency to perform this kind of surgery at very young age, which is due to the sensitivity of this period in child's learning. Several studies have shown that the age of the child at surgery and duration of using cochlear implant prosthesis are very important in his/her success at speech comprehension [5]. In this respect, the children with lower age at implantation show better and higher performance than those undergoing implantation at older ages [6].

The deaf children are prone to delayed speech development, which may adversely affect their growth, education, compatibility, and interactions [1]. More than two decades of experience has shown that cochlear implantation has a significant effect on speech and sound comprehension as well as improvement of speech development, language, and communication skills [2, 4]. In a study conducted in

2008, verbal intelligence was compared between the normal and deaf children after cochlear implantation and rehabilitation. In the mentioned study, verbal intelligence was evaluated in many language skills, which was not measurable previously in deaf people, and a significant success was reported [7].

Some children with cochlear implant show a significant improvement in language development and progress up to the level of normal people; however, this is not the case for everyone [8, 9]. Meanwhile, the implementation of cochlear implantation at a younger age, and also continuation of persistent training post-surgery result in improved language development [10]. The individuals receiving cochlear implant in their left or right ear demonstrate significant differences in speech and auditory performance, and it is constant at two intervals. This suggests that the right cochlea users can adopt better lexical knowledge; therefore, they show higher levels of performance in this regard.

In further confirmation for the advantage of right ear cochlear implantation, studies have shown that the performance of the children with right-sided deafness in the linguistic test of Wechsler's intelligence scale was significantly lower than that of the left-sided deaf subjects; accordingly, these children were at greater risk for educational problems [11, 12]. Primary information shows that bilateral cochlear implantation simultaneously represents the significant advantage of the right ear for speech development.

Similarly, other reports on children with normal hearing indicates the advantage of the right ear for speech with increasing age and enhanced hearing-talking experience [13-15]. Deafness before speaking also supports the benefit of right cochlear implantation, which shows similar brain activity patterns in children with cochlear implant in the right side. In contrast, the children undergoing cochlear implantation on the left ear show the activation on the same side [16].

Therefore, it is possible that the children receiving cochlear implant on the left side develop compensatory activation patterns as a result of the reorganization in the specializations of the applied professions [17]. With this background in mind, the present study aimed to compare the IQ of the children aged 4-16 years after cochlear implantation in the left or right ear during 2008-2011.

Materials & methods

This cross-sectional study was conducted on 4-16 year-old children referred to Khorasan Cochlear Implantation Center, Iran for undergoing cochlear implantation in the left or right ear during 2008-2011. For the purpose of the study, all recorded variables were studied, such as age, gender, family history, congenital neurological diseases, history of familial mental retardation, etc. The study population was selected using census sampling.

First, we made a questionnaire and coordinated with the Khorasan Cochlear Implantation Center (Pejwak Auditory) in order to examine the medical records of the children aged 4-16 years receiving cochlear implant within 2008-2011. The questionnaire included such data as name, age, gender, family history, date of cochlear implantation, IQ subcategories (i.e., general information, mathematics, similarities, words, and comprehension), and language development. The deaf children receiving cochlear implant in the past three years with no other disabilities were included in the study.

The determination of three years of implantation interval was due to the fact that children experience minimum changes in IQ, established by social communication and education, within this period. On the other hand, the exclusion criteria included: 1) lack of child's cooperation in IQ test, 2) congenital neurological diseases, 3) family history of mental retardation, and 4) any ear disorders.

After obtaining informed consent from all parents, the patients' IQ was measured by a neuroscientist using the Wechsler test [18]. This test

consists of five topics including: 1) general information (child's awareness of incidents, individuals, places, and important people), 2) mathematics (a set of mathematical problems that the child can solve mentally and express the result verbally), 3) similarities (a set of concepts and words that the child can express immediately), 4) words (child should be able to explain the meaning of some words), and 5) comprehension (a set of events the child needs to solve as everyday problems). This test had its own standard process, which was followed in the present study (3).

The validity and reliability of this test were determined in Iran. The validity of test was within 0.69-0.24, and its reliability coefficient varied from 0.44-0.94. The standardization of this test was also performed by Sharifi et al. [19]. Finally, the IQ of the patients who had the cochlear implant on the right side was compared to those with implants on the left side.

Statistical analysis

Chi-square and Fisher's exact tests were employed to analyze the nominal variables. The normality of the quantitative variables was tested using Kolmogorov-Simonov test. In addition, the dependent variables were compared by means of the independent sample t-test and Wilcoxon test for the normally and non-normally distributed data, respectively. Data analysis was performed in SPSS version 18.

Results

Out of 40 subjects, 21 (52.5%) cases were female. Furthermore, 10 (25%) patients had a family history of ear disorder. The paternal education levels of 25 (62.5%) and 15 (37.5%) participants were under diploma and diploma or higher, respectively. Regarding the maternal education level, 28 (70%) and 12 (30%) patients' mothers had under diploma or equal and higher than diploma education, respectively. In terms of the family income status, 28 (70%) and 12 (30%) cases earned less than 250$ and within 250-500$ a month, respectively.

The predominant hand was the left one in 14 (35%) subjects and right hand in 26 (65%) participants before the surgery. Cochlear implantation was performed on 26 (65%) and 14 (35%) patients with right and left ear problems, respectively. The IQ levels were low, relatively low, poorly normal, normal, and smart in 32.5 (13%), 13 (32.5%), 8 (20%), 5 (12.5%), and 1 (2.5%) cases, respectively. Demographic and other variables in each group represents in Table 1.

The assessment of the distribution of preoperative predominant hand frequency according to IQ revealed no significant difference between the frequency of the predominant right and left hand (P=0.505). The preoperative evaluation of IQ according to predominant hand demonstrated no significant association between the children with right and left predominant hands (P=0.687). Furthermore, based on the evaluation of the relationship between the implanted ears and gender, no significant difference was observed between the two groups (P=0.816). Additionally, no significant difference was found between the children with right and left implanted ears in terms of family history, parental education level, predominant hand, income level, and IQ

(P>0.05) (Table 2).

Discussion

So far, no study has been performed to investigate the association between intelligence and the predominant brain hemisphere in cochlear implanted children. In this study, we aimed to compare the left- and right-handed children undergoing left or right cochlear implantation in terms of intelligence. To this aim, the relationship between the predominant cerebral hemisphere and intelligence level in these children was also evaluated. The findings of the present study revealed no association between the right- or left-cochlear implanted ear and the children's IQ.

Many studies have examined the causes of the hemispheric dominance resulting in the right- or left-handedness of individuals. Meanwhile, genetic factor has been shown to be a play a major role in this regard in various studies [20]. Moreover, the role of environmental factors, such as hormonal factors, emphasized on intrauterine environment and fetal development, birth stress, low birth weight, as well as cultural, social and psychological factors [21-23].

Meland et al. (2009) in a large-scale study examined the role of genetics in dominant hand. Based on their findings, the contribution of environmental factors in this regard were three times greater than that of the genetic agents [24]. There is a controversy about the contribution of genetic and environmental factors in the determination of dominant hands among the researchers. Mehram et al. (2013) studied the children who were at the age of dominant hand development. Accordingly, they reported no significant difference in the left- and right-handed children in both groups of males and females, which was suggestive of the preference of environmental factors [25].

According to the literature, hemispheric dominance occurs among 50% and 90% of the children aged 3 and < 6 years, respectively [26]. The present study was conducted on the children aged within 4-16 years, and the findings indicated no correlation between intelligence and dominant hemisphere. However, some studies have shown that the left-handed people have higher intelligence and abilities, compared to the right-handed individuals [27-30]. However, some studies have reported contradictory findings in this regard [31]. Additionally, most of the studies suggest that the ambidextrous people having no specialized hemisphere have lower levels of intelligence and skills than others [32, 33].

According to a hypothesis, the intelligence level of the left-handed people is higher than that of the other people [34, 35]. In this regard, a study examined the difference between the left- and right-handed children regarding the results of the intelligence tests. Based on

findings of the mentioned study, there was no significant relationship between the outcomes of intelligence tests and educational readiness of the left- and right-handed children [25], which is consistent with the results of the present study. Given the fact that the brain growth is associated with neuronal stimuli, it is expected that cochlear implantation leads to changes in brain function due to neuronal stimulation [36].

In another study conducted in Australia, 5,000 children aged 4-5 years were examined [22]. The findings of the mentioned study indicated lower scores for the left-handed and ambidextrous children, compared to the right-handed cases. The mentioned study also revealed the role of gender in this regard; accordingly, this difference was mostly observed among the males than females, which is inconsistent with the findings obtained in the present study.

Unilateral cochlear implants play a significant role in speech and sound comprehension, and thereby speech improvement as well as development of language and communication skills [20, 23].
Considering the children's high sensitivity to learning at early age, there is now strong tendency to perform a cochlear implantation at very younger ages [5, 6].

According to the findings of a study conducted by Witelson et al. (2005), the right-handed men had only higher verbal intelligence, compared to the other people. However, this difference was not reported in women [37]. In a study carried out by Alibeik et al. (2011), a significant statistical difference was observed between the left- and right-handed adults in terms of their intelligence. They showed that despite the dominant hand, there can be a relationship between the level of intelligence and the other predominant organs in the body [38].

The left-handed individuals show more diffused brain structure in terms of some functional superiority variables, compared to the righthanded people. Based on the data obtained from magnetic resonance imaging, combined hand movement in the left-handed

individuals involve higher volumes and more areas rather than that in the righthanded people [39, 40]. In a study comparing the normal and deaf children regarding verbal intelligence following cochlear implantation and rehabilitation, the retesting of verbal intelligence demonstrated significant advancement in many language skills in the deaf people. This increase was significant in the children with cochlear implant. Furthermore, some of these children attained normal level of language development as that of the other member of the society [9].

Other benefits of right ear cochlear implantation has been shown in some studies [14]. According to a study conducted by Sandford (2002), there was a significant difference in the speech and hearing performance of those undergoing cochlear implantation on left and right ears. In this regard, the children receiving implantation, showed better lexical knowledge and language performance. However, these features were not observed in our study [4].

Based on the data obtained from the previous studies, the performance of children with hearing impairment in the right ear in the linguistic test of Wechsler's intelligence scale was much lower than those with left ear hearing impairment. Accordingly, these children were at greater risk for educational problems [11, 12, 15]. A remarkable ability was observed in the speech of the children having bilateral cochlear implantation, compared to that of the others. Similarly, in normal children, the ability of the right ear improves for speech with increasing age and linguistic hearing experience [13].

Kileny et al. (2004) reported the same brain activity patterns in the children with cochlear implantation on the right side. On the other hand, they reported activation of the same side among children who performed the implantation on their left side [16]. Therefore, the children with cochlear implant on the left ear may develop an acute compensatory pattern as a result of reorganization in applied specialties [17, 41, 42].

Based on the aforementioned findings, and regarding the contradictory results in different studies, no definitive concept could be yielded in this regard. It is possible that the results of various examinations are influenced by a variety of factors, such as age and employment of different methods or tests. According to the results of the present study, the children's IQ had no relationship with the side of the cochlear implantation.

The findings of the present study can be used as the basis for future research on the association between brain intelligence and its lateral dominance. These findings can be also used by the pediatricians, including occupational therapists and psychologists, in order to assess the movement and rehabilitation of low IQ and retarded children. The limitations of this study included the employment of small sample size and use of only one method (i.e., Wechsler test). Further studies are recommended to use a larger sample size and other research instruments.

Conclusion

As the findings of the present study indicated, there was no relationship between the dominant hand and IQ score in the children undergoing cochlear implantation.

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Tables

Table 1. Descriptive information of study population

		Case		Control		Total			Pvalue
Gender	Male	12	46.2	9	64.3	21	51	01.2	0.27
	Female	14	53.8	5	35.7	19	46		

Family history	Yes	19	73.1	11	78.6	30	75	0.14	0.702
	No	7	26.9	3	21.4	10	25		
Paternal education level	Under diploma	17	65.4	8	57.1	25	62.5	0.26	0.608
	Diploma and higher	9	34.6	6	42.9	15	37.5		
Maternal education level	Under diploma	18	69.2	10	71.4	28	70	0.02	0.88
	Diploma and higher	8	30.8	4	28.6	12	30		
Family's income level	Less than 250$	19	73.1	9	64.3	28	70	0.33	0.56
	250-500$	7	26.9	5	35.7	12	30		
Predominant hand before surgery	Right	17	65.4	9	64.3	26	65	0.005	0.94
	Left	9	34.6	5	35.7	14	35		
Cochlear implantation	Right	18	69.2	8	57.1	26	65	0.58	0.44
	Left	8	30.8	6	42.9	14	35		
IQ	Low	9	34.6	4	28.6	13	32.5	42.54	0.63
	Relatively low	8	30.8	5	35.7	13	32.5		

	Poor normal	5	19.2	3	21.4	8	20.0		
	Smart	0	0	1	7.1	1	2.5		
	Normal	4	15.4	1	7.1	5	12.5		

Table 2. Evaluation of the operated ear based on IQ

Operated ear	**IQ**						**Pvalue**
	Low	Relatively low	Poor normal	Normal	Smart	Total	
Right (%)	10 (25%)	9 (22.5%)	5 (12.5%)	1 (2.5%)	1 (2.5%)	26 (65%)	0.209
Left (%)	3 (7.5%)	4 (10%)	3 (7.5%)	4 (10%)	0 (0%)	14 (35%)	