Vowel Production in Persian Deaf Children with Cochlear Implant: is the Age of Implantation an Important Factor?

Peyman Zamani · Amir Rahmanirasa · Farzad Weisi · Ayub Valadbeigi · Farhad Farahani · Mohammad Rezaei

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Abstract Proper production of vowels has great significance in speech intelligibility. Evidence shows that cochlear implantation has a significant impact on language and reading abilities in some children immediately after the surgery. The aim of the present study is comparing the quality of 6 simple Persian vowels between two groups of cochlear-implanted children under and over 2 years old. This was a cross-sectional analytic study conducted on 70 children who were implanted under the age of 2, 70 children who were implanted over the age of 2 and 238 normal children as control group. For data analysis, the SFS win acoustic analysis was used. Result of this study showed that F2/i/, f1/e/, f2/e/, f2/∞/, f1/a/, F2/a/, f1/o/, F2/o/and F2/u/ means had significant difference between three groups ($P < 0.05$). Children implanted under the age of 2 showed similar performance as normal children in vowel production. Early cochlear implantation (under the age of 2) affects the quality of simple Persian vowel production significantly as well as the increase of speech intelligibility.

Keywords Vowel production · Deaf children · Cochlear implantation

Introduction

Proper production of vowels has great significance in speech as they are not only structural blocks of words, but also form plosive consonants. The rhyme and prosody of speech are affected by the way vowels are formulated [1]. Thus, production of vowels seems to be an important communicative ability. Some researchers believe that improving the vowel production is 41–53 % effective in speech intelligibility [2, 3] Therefore, speech and language pathologists are interested in modification of vowel production in Deaf people [4].

Through extensive surveys on auditory, language and speech skills of deaf children with cochlear implant, it has been found that they show more considerable perceptual and productive improvement in comparison to deaf children with hearing aids [5]. Evidence shows that cochlear implantation has a significant impact on language and reading abilities in some children immediately after the surgery [6].

Majority of the studies indicate that early cochlear implantation causes shortening the period of auditory deprivation, leading to prevention of inappropriate perceptual and expressive learning (especially for auditory and acoustic vowels). Consequently, the child is allowed to have the right and comprehensive experiences of the environment [7–12]. However, some researches do not consider the effect of the age of implantation as a fundamental factor. For instance, Myamoto et al. [13] believe that the age of implantation has effect on speech intelligibility but this effect is not statistically significant. Geers et al. [14, 15] confirming Miamoto expressed that early

P. Zamani
Musculoskeletal Rehabilitation Research Center, Ahvaz
Jundishapur University of Medical Sciences, Ahvaz, Iran

A. Rahmanirasa · M. Rezaei (✉)
Faculty of Rehabilitation Sciences, Hamadan University of
Medical Sciences & Health Services, Hamadan, Iran
e-mail: m_r_st@yahoo.com

F. Weisi · A. Valadbeigi
Iran University of Medical Science & Health Services, Tehran,
Iran

F. Farahani
Faculty of Medical Sciences, Hamadan University of Medical
Sciences & Health Services, Hamadan, Iran

cochlear implantation can not ensure reaching natural levels of perception, speech and reading skills.

In spite of improvements in prosthesis, noble surgical techniques and auditory-verbal rehabilitation strategies, cochlear implant users are not capable of receiving the whole voice spectrum of speech [16]. This might have negative effects on the ability of proper vocalization ability particularly vowels. National institute of health in 1995 proposed that cochlear implantation should be done under the age of 2 in order to enhance the speech and language skills. While some implants are applied over 2 years old [17].

According to previous studies, using cochlear implants in younger ages resulted in better perception of speech, modification of vowel recognition and production in people with hearing loss [5, 12].

Some studies assume that the age of implantation has significant effect on expressive speech skills and speech intelligibility [18, 19]. The main question is in what age in the implantation could affect the ability to produce vowels properly in cochlear-implanted children; and how it is compared with normal children?

Considering the lack of information in the area of vowel production as well as insufficient researches on Persian-speaking children of different ages with cochlear implantation, the aim of the present study is comparing the quality of six simple Persian vowels between two groups of cochlear-implanted children under and over 2 years old.

Methods

This study was a cross-sectional descriptive and analytic study conducted on 70 children (32 male, 38 female) who were implanted under the age of 2 and 70 children (35 male, 35 female) who were implanted after the age of 2. The participants were extracted from hospitals of Tehran University of medical sciences. The inclusion criteria were: Receiving 9 ± 1 months rehabilitation after surgery, 9 ± 2 months using implants, healthy oral organs related to speech production and unilateral application of the implant. History of epilepsy, seizure, faint, head injury, bilinguality of child or parents, neuromuscular deficits such as cerebral palsy and parents hearing lost, consisted the exclusion criteria.

In fact, the sample had no adjunct complication except for hewing loss. As control group, 238 normal children (110 male, 128 female) with the mean age of 52.13 ± 9.36 months were randomly selected from 20 zones of Tehran kindergartens. For vowels analysis speech samples including six unisyllabic standard vocal contexts, [hud, hod, had, hoed, hed, hid] were tape recorded and played

for children, then they were asked to repeat each word after listening [17].

Because children had no semantically comprehension of informationed non-words, bisyllabic meaningful words /ناهید، شاهد، أحد، فرهاد، فرهودهد/ were used. These meaningful words consisted of two unmeaningful syllables.

Getting speech samples was as follows: after displaying and teaching a word, the first and second (non words) syllables of the word were respectively expressed respectively by the examiner and the child. For example, for non word of /hid/, after displaying and teaching /Nahid/, the first syllable, /Na/ and immediately the second one, /hid/ were pronounced by the examiner and the child consecutively. Both voices were recorded on the software. Afterwards, voice spectrum /hid/ was simply detected by SFS software.

The first middle 30 ms of the vowel spectrum is detected and related numbers were written in first and second formant frequencies (first and second formant frequency are measured to assess the vowels pronunciation¹).

By understanding these two voice parameters, the appropriate vowel pronunciation can be determined [20].

Hence, each Persian vowel has two formant frequencies. To simplify, each formant frequency is abbreviated.

For instance the first and second vowel formant of /i/ are abbreviated f1/i/ and f2/i/. For data analysis, the SFS win² acoustic analysis was used [21].

A SHURE BG 1.1/C15AHZ/Pin2Hot Microphone made in Mexico and a dell Inspiron 1300 Malaysian were also applied for speech sampling.

Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 16. The descriptive measures were mean and standard deviation. To assess the association between variables the following steps were consecutively followed: measurement of simple percentages, independent *t* test and univariate analysis of variance (ANOVA). The significance level was 0.05.

To confide the reliability of SFS win in Persian language, it was tested on 16 cochlear-implanted children. Test–retest was conducted periodically three times with a 3-day interval of each sampling. The correlation coefficients between three tests were high ($r > 0.880$).

¹ Vibration of the vocal cords provides sound source. This sound source consists of a fundamental frequency and its harmonics that are multiples of the fundamental frequency. Then this sound is changed with shape of oral cavity. The speech cavity acts like a filter and strengthening some harmonic frequencies and weakening others. Those Frequencies that strengthened are called “Formant”. Formants generally determine the differences between the vowels [20].

² Speech Filing System.

Results

The mean age at implantation and chronological age of children who were implanted under 2 years old was 22 ± 1 and 32.53 ± 1.8 months respectively and in children who were implanted over 2 years old was 28 ± 1 and 37.74 ± 1.7 months.

Table 1 indicates results related to the mean and SD of the first and second formant frequencies of simple Persian vowels in three groups of participants: cochlear-implanted under 2 years old, over 2 years old and normal ones.

According to the one-way ANOVA, F2/i/, f1/e/, f2/e/, f2/o/, f1/a/, F2/a/, f1/o/, F2/o/and F2/u/means had significant difference between three groups (Table 2).

As presented in Table 1, mean scores of F2/a/, F2/u/, F2/ae/, F2/e/and F2/o/were significantly different between the implanted children under and over 2 years old. Also F1/a/, F2/i/, F2/u/, F2/ae/, F1/e/, F2/e/, F1/o/and F2/o/means had significant difference between normal children and implanted children over 2 years old, while there was no significant difference between normal children and implanted children under 2 years old.

Table 1 THE comparison of the vowel production score for cochlear implanted and normal children

Variable (vowel)	Group	M	SD	Pv (over2/under 2)	Pv (normal/under 2)	Pv (normal/over 2)
F1/a/	Normal	988.13	100.002		0.904	
	Implantation under 2	994.64	122.406			0.019
	Implantation over 2	1029.13	111.859	0.162		
F2/a/	Normal	1513.30	163.375		0.352	
	Implantation under 2	1478.19	186.165			0.111
	Implantation over 2	1564.36	215.956	0.018		
F1/i/	normal	435.98	68.865		0.977	
	Implantation under 2	434.10	59.615			0.218
	Implantation over 2	420.79	48.500	0.469		
F2/i/	Normal	2887.92	171.712		0.521	
	Implantation under 2	2863.16	138.686			0.01
	Implantation over 2	2808.40	133.121	0.129		
F1/u/	Normal	439.85	59.522		0.706	
	Implantation under 2	433.29	28.917			0.913
	Implantation over 2	436.50	71.691	0.947		
F2/u/	Normal	1033.68	69.251		1	
	Implantation under 2	1033.49	39.842			0.00
	Implantation over 2	1196.71	149.181	0.00		
F1/æ/	Normal	1194.18	119.659		0.394	
	Implantation under 2	1214.54	81.191			0.179
	Implantation over 2	1221.91	97.843	0.924		
F2/æ/	Normal	2164.77	277.153		0.878	
	Implantation under 2	2182.81	244.627			0.041
	Implantation over 2	2075.11	207.533	0.045		
F1/e/	Normal	687.55	113.823		0.530	
	Implantation under 2	672.07	70.567			0.002
	Implantation over 2	637.94	76.825	0.137		
F2/e/	Normal	2412.83	252.941		0.845	
	Implantation under 2	2433.73	333.510			0.00
	Implantation over 2	2579.69	223.769	0.005		
F1/o/	Normal	603.43	78.612		0.724	
	Implantation under 2	611.97	70.743			0.047
	Implantation over 2	629.84	83.581	0.402		
F2/o/	Normal	1206.54	114.074		0.962	
	Implantation under 2	1202.04	122.129			0.005
	Implantation over 2	1259.81	131.828	0.017		

Table 2 Effect of age at implantation on vowel production

		ss	df	ms	F	Sig
F1a	Between groups	91368.195	2	45684.097	4.015	0.019
	Within groups	4267274.876	375	11379.400		
	Totals	4358643.071	377			
F2a	Between groups	265496.648	2	132748.324	4.171	0.016
	Within groups	11935164.476	375	31827.105		
	Totals	12200661.124	377			
F1i	Between groups	12627.424	2	6313.712	1.546	0.214
	Within groups	1531462.981	375	4083.901		
	Totals	1544090.405	377			
F2i	Between groups	344633.123	2	172316.562	6.775	0.001
	Within groups	9537856.710	375	25434.285		
	Totals	9882489.833	377			
F1u	Between groups	2526.594	2	1263.297	0.378	0.685
	Within groups	1251976.340	375	3338.604		
	Totals	1254502.934	377			
F2u	Between groups	1516808.019	2	758404.010	102.240	0.000
	Within groups	2781693.137	375	7417.848		
	Totals	4298501.156	377			
F1ae	Between groups	52895.846	2	26447.923	2.200	0.112
	Within groups	4508811.445	375	12023.497		
	Totals	4561707.291	377			
F2ae	Between groups	518978.515	2	259489.257	3.845	0.022
	Within groups	25305779.961	375	67482.080		
	Totals	25824758.476	377			
F1e	Between groups	134121.188	2	67060.594	6.581	0.002
	Within groups	3821343.309	375	10190.249		
	Totals	3955464.497	377			
F2e	Between groups	1522502.013	2	761251.006	10.857	0.000
	Within groups	26292900.866	375	70114.402		
	Totals	27815402.878	377			
F1o	Between groups	38094.933	2	19047.466	3.116	0.045
	Within groups	2291947.639	375	6111.860		
	Totals	2330042.571	377			
F2o	Between groups	169253.955	2	84626.977	5.974	0.003
	Within groups	5312322.617	375	14166.194		
	Totals	5481576.571	377			

Also, the vowel plot of three groups of studied children was respectively presented (Figs. 1, 2, 3).

Discussion

The result of this study indicate the significant difference of vowel production among children implanted at different ages. significant differences in speech and language skills of children implanted at different ages are proven through other studies for instance, it has been found that children implanted under 5 years old, showed better performance in

speech production tasks than the ones implanted over the age of five [22]. Also Svirsky et al. [23] compared the scores derived from production tasks in implanted children and observed more precise production in children implanted under the age of 36 months than children over that age.

Some researchers believe that cochlear implantation in lower ages provokes better perception of speech and their subsequent reading abilities. So, the age of implantation affects significantly expressive speech skills and speech intelligibility [19, 23]. It should be mentioned that other factors such as the type of prosthesis, quality of post

Fig. 1 The vowel plot related to typical Persian children

Fig. 2 The vowel plot related to Persian children implanted under 2 years old

surgical education and the child's IQ has effects on the acquisition of speech and language skills [6].

Proper production of vowels is a verbal ability upon which the child's speech and language skills can be evaluated. As shown in results, there is significant difference in production of each six Persian vowels between children implanted under 2 years old and those over the age of 2.

Improvement in quality of vowel production in children implanted under 2 years old is obvious when it is compared with normal children. According to results, no significant difference in vowel production is observed between normal children and children implanted under the age of 2. However, there has been significant difference (at least in one vowel formant frequency) between normal children and children implanted over 2 years old.

Fig. 3 The vowel plot related to Persian children implanted over 2 years old

Conclusion

As indicated in this study, children implanted under the age of 2 has difference with children implanted over 2 years old in production of all Persian vowel. Meanwhile, there was no significant difference between normal children and children implanted under 2 years old in this item. However, children implanted over the age of 2 were different from the normal children at least in one vowel formant frequency. The difference in production of simple vowels between this group and the normal one might be resulted from the shortening of the auditory deprivation before cochlear implantation. Therefore, considering results of our study, it could be claimed that early cochlear implantation (under the age of 2) affects the quality of simple Persian vowel production significantly as well as the increase of speech intelligibility.

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