Research Article

Consonant Production Skills in Children with Cochlear Implants and Normal-Hearing Children Aged 3–5 Years

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Highlights

- Children with CI have difficulty producing speech sounds 1–3 years after surgery
- Children with CI have similar learning sounds production skills compared to NH peers

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ABSTRACT

Background and Aim: Consonant development plays a significant role in speech intelligibility which is impaired in children with profound hearing loss. Cochlear implant (CI) can facilitate the development of language comprehension and sound production in children with severe to profound sensorineural hearing loss. This study aimed to compare consonant production skills in children with CI and normal-hearing (NH) children aged 3–5 years.

Methods: In this cross-sectional study, participants were 20 children with CI and 20 age-matched NH children. The consonant production skills were assessed using the speech intelligibility test in Persian.

Results: There were significant differences between CI and NH children ($p<0.05$), where the highest percentage of correct production in both groups was related to the manner of articulation of stop and nasal consonants. NH children showed less accuracy only in /r/ and /ʧ/, while children with CI were less accurate in /q/, /x/, /ʤ/, /l/, /j/, and /r/.

Conclusion: Children with CI have lower scores compared to age-matched NH peers, but they have similar consonant production skills.

Keywords: Cochlear implant; consonant production; consonant accuracy

Introduction

Auditory input is one of the most important components in acquisition and accurate production of speech sounds [1]. Hearing loss in children can cause problems in distinguishing different phonemes from each other, which may cause speech sound disorders [2]. Previous studies have found that children with profound hearing loss have difficulty in producing speech sounds and, thus, show a variety of speech disorders [3,4]. In recent years, newborn hearing screening and advancement in cochlear implantation have raised hope for children with hearing loss [5]. Cochlear implant (CI) is an electronic device that stimulates surviving cells of the auditory nerve and provides access to sounds. This sensory restoration can facilitate the development of language comprehension and production in children with severe to profound sensorineural hearing loss [6]. However, little is known about the extent to which cochlear implantation can facilitate consonant production skills in CI users. Some studies have shown that children with CI earn a higher score in consonant accuracy tests and consonant inventories, but they are far behind normal children, especially age-matched peers [7-9]. Serry and Blamey evaluated consonant production skills in children with CI and reported that the upward growth of consonant production begins after one year of implantation [10]. Blamey et al. evaluated the inventories of CI children aged 2–5 years and reported that consonant inventories were dominated by nasal and stop after one year of using CI [11]. Shamsian et al. examined the speech sample of 20 children with CI in terms of production errors. They reported that consonant production errors declined significantly after two years of cochlear implantation [12]. Fatemi Syadar et al. studied correct consonant production in Kurdish-speaking children aged 3–5 years in Iran. They indicated that normal children had more accuracy in producing nasal consonants followed by glide, stop, fricative, affricate, and trill consonants [13]. Sohrabi et al. studied speech intelligibility in children with CI and normal-hearing (NH) children aged 3–5 years. According to their results, the correct percentage of words written down by inexperienced listeners was 57.75% in children with CI and 96.10% in NH children. Moreover, the correct percentage of words transcribed by speech therapists was 58.50% in children with CI and 96.55% in NH children [14]. Damerchi et al. investigated development of phonetic inventory in Persian-speaking children aged 2–6 years. They concluded that nasals and plosive bilabials were the first consonants produced correctly by most children. In their study, /m/ was the only consonant that all children pronounced correctly [15]. Since there is little information about consonant production characteristics of children after cochlear implantation, this study aimed to compare consonant acquisition of Persian-speaking children with CI and NH children using the speech intelligibility test. Moreover, we compared the effect of manner of articulation on consonant accuracy between two groups of children. These comparisons can help us understand whether children with CI can produce consonants as accurately as their age-matched peers.

Methods

Participants

In this study, participants were 40 monolingual Persian-speaking children, 20 with CI aged 36–62 months (mean age =53.75 ±7.95 months) and 20 age-matched NH children (mean age=53.60±8.17 months). They had no history of neurological problems, seizures, physical disability, or any other disorders. They were divided into two groups. Children with CI were randomly selected from those referred to Baqiyatallah Hospital and NH children were recruited from a kindergarten in Tehran, Iran. Children with CI had an ability to produce at least two-word sentences and the number of their expression vocabulary were at least 100 words. All CI children had bilateral congenital severe-to-profound sensorineural hearing loss (71+ dB HL) before cochlear implantation, and at least one year had passed since their implantation. All NH children were at normal range according to the ages and stages questionnaire score, which was completed by their parents. Based on the clinical assessment, these children had no oral-motor disorders. They had no hearing problems according to parental reports and medical records.

Speech intelligibility test

The speech intelligibility test used in this study was the test designed by Heydari et al. [16] for Persian-speaking children aged 3–5 years, which includes 47 pictures. According to them, speech intelligibility ranges from 72.41% to 86.2% in 3–5 years old normal children. The test-retest reliability of this test using intra class correlation coefficient (ICC) is 0.85, indicating that this test is repeatable. It also has acceptable content validity ratio (CVR=0.75) [16]. This test covers all phonemes (Table 1). Based on the manner of articulation, these consonants can be classified into six categories including stops (/p/, /b/, /t/, /d/, /c/, /g/, /q/, and /ʔ/), nasals (/m/ and /n/), fricatives (/s/, /ʃ/, /z/, /f/, /v/, /x/, and /h/), affricate (/ʧ/ and /ʤ/), liquid (/j/ and /l/), and trill (/r/). The test was con-

Table 1. Speech intelligibility test for Persian-speaking children presented phonetically

Number	Word	Word (in English)	Syllables	Number	Word	Word (in English)	Syllables
1	sib	apple	cvc	25	ʔadambarfi	snowman	cv.cvc.cvc.cv
2	mouz	banana	cvc	26	sibzamini	potato	cvc.cv.cv.cv
3	pa	foot	cv	27	macaroni	macaroni	cv.cv.cv.cv
4	tut	berry	cvc	28	tutfarangi	strawberry	cvc.cv.cvc.cv
5	muʃ	mouse	cvc	29	havapejma	plane	cv.cv.cvc.cv
6	kif	bag	cvc	30	tup	ball	cvc
7	dast	hand	cvcc	31	miz	table	cvc
8	ceic	cake	cvc	32	guʃ	ear	cvc
9	gol	flower	cvc	33	fil	elephant	cvc
10	mahi	fish	cv.cv	34	ʃir	lion	cvc
11	deraxt	tree	cv.cvcc	35	cafʃ	shoe	cvcc
12	lacpoʃt	turtle	cvc.cvcc	36	susc	cockroach	cvcc
13	mesvak	toothbrush	cvc.cvc	37	tab	swing	cvc
14	Gejʧi	scissor	cvc.cv	38	colah	hat	cv.cvc
15	celid	key	cv.cvc	39	ʧeʃm	eye	cvcc
16	xijar	cucumbers	cv.cvc	40	ʔejnac	glasses	cvc.cvc
17	livan	glass	cv.cvc	41	havidʒ	carrot	cv.cvc
18	ʧangal	fork	cvc.cvc	42	ʔangur	grapes	cvc.cvc
19	doʧarxe	bicycle	cv.cvc.cv	43	parvaneh	butterfly	cvc.cv.cv
20	zarrafe	giraffe	cvc.cv.cv	44	telefon	phone	cv.cv.cvc
21	qurbaqe	frog	cvc.cv.cv	45	bastani	ice cream	cvc.cv.cv
22	porteqal	orange	cvc.cv.cvc	46	badconac	ballon	cvc.cv.cvc
23	ʔotobus	bus	cv.cv.cvc	47	qaʃoq	spoon	cv.cvc
24	sandali	chair	cvc.cv.cv				

ducted individually for each child in a quiet room. Each colored picture was displayed on a laptop screen with an interval of three seconds. The children were asked to name the pictures that they see. During the test, the examiner did not correct or repeat any words for children. If the child was not able to name the picture, it would be removed from the samples. The children's voices were recorded by a digital voice recorder (Kingston DVD-902) that was placed at a distance of about 40 cm away from the speaker.

The collected data were copied onto a CD and was given to 10 NH young listeners aged 20–30 years (mean age=25 years). They were speech therapists that were familiar with transcription. Each listener received 4 CDs given randomly to reduce the possibility of sounds prediction [16]. They listened to the sounds in a quiet environment and transcribed them. After the end of transcriptions, the examiner counted the number of each child who produced each consonant correctly and divided by the total number of children to calculate the correct consonant production rate. Since all consonants are repeated more than twice in the test, a consonant was considered correct if the target consonant was produced correctly at least two times [11]. Since the result of our study are based on the correct transcription rate, 30% of speech samples (12 children) were randomly selected and re-transcribed by a second listener to examine inter-rater reliability [17]. The point-to-point comparisons between the transcriptions of first and second listeners were conducted. The average inter-rater agreement between two listeners was more than 90% for 12 transcribed speech samples.

Data analysis

Statistical analysis was carried out in SPSS v.17 software using the mean and standard deviation of the scores for each consonant. Kolmogorov-Smirnov test results indicated that the data were normally distributed ($p<0.05$). To compare the groups, t-test was used.

Results

Table 2 presents the characteristics of participants. All speech sounds were produced at least in 50% of participants. Figure 1 depicts the correct consonant production scores between NH and CI children. NH children were more accurate in producing nasals (/m/, /n/), and /ʔ/ and lower accurate in /r/, and /ʧ/. Children with CI were more accurate in producing nasals and stops (/b/, /p/, /ʔ/), and lower accurate in /q/, /x/, /ʤ/, /l/, /j/, and /r/. There was a significant difference in production of all consonants between the two groups of children ($p<0.05$).

Discussion

The current study examined consonant acquisition in children with CI and NH children. The results showed that the children with CI had lower consonant production scores compared to NH children. This indicates that these children still have difficulty producing speech sounds 1–3 years after surgery. The difference between the two groups was due to the fact that children with CI have less auditory experience compared to NH children. They have no auditory input in the first two years of life, which is a sensitive period of language learning. This prevents speech organs from having enough time to practice and, thus, delays the development of oral-motor coordination. The results of this study supports the findings of some previous studies in this area. Many previous studies have shown that children with CI lag

Table 2. Mean, standard deviation, range of chronological age, age of implantation in children with cochlear implant, and normal-hearing children

Group	Number	Gender (female/male)	Chronological age (month)		Age of implantation (month)	
			Mean (SD)	Range	Mean (SD)	Range
Children with CI	20	12/8	53.75 (7.95)	38–64	29.2 (8.01)	24–48
NH children	20	9/11	53.60 (8.17)	38–64		

CI; cochlear implant, NH; normal-hearing

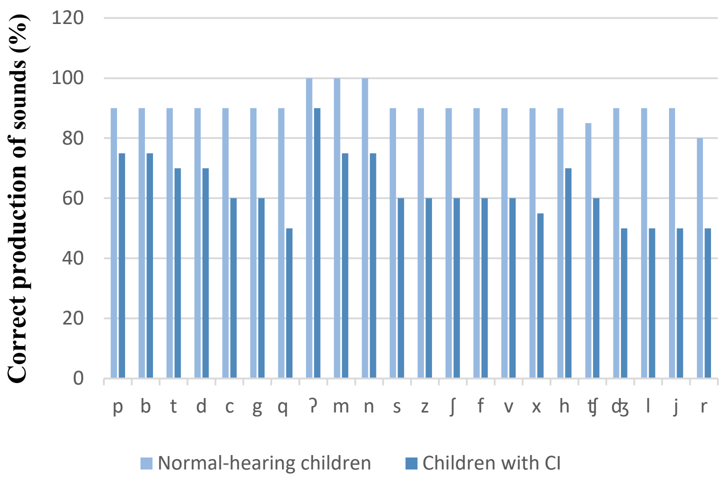

Figure 1. Correct production of speech sounds in children with cochlear implant and normal hearing children

behind NH children in production of consonants [7, 8, 18]. Ertmer and Jung stated that children with CI have a significant delay in consonant production after two years of surgery [19]. In our study, more than 50% of children with CI regained the ability to produce most Persian speech sounds and had similar consonant inventory as NH children. This is consistent with the findings of Sundarrajan et al., Schauwers et al., and Salas-Provance et al. [20-22]. Sundarrajan et al. compared consonant production in children with CI and NH children at 3.5 and 4.5 years of age. They showed that children using CI had lower scores than NH children; however, they had performance similar to that of NH children in speech sound production [20]. Schauwers et al. concluded that children with CI had similar consonant inventory as NH children [21]. Salas-Provance et al. compared consonant inventory in 3.5-year-old NH children and CI children with 7–27 months of hearing experience. According to them, consonant inventories were similar in two groups and included the plosive, fricative, affricate, nasal, liquid, and trill consonants [22].

The results of this study showed that participants were more accurate in producing stop and nasal consonants based on the manner of articulation. Similarly, Peng et al. revealed that children with CI were able to produce stops and nasals more accurately than other consonants [23]. Tye-Murray et al. studied consonant production in children with CI with 36 months of auditory experience. It was reported that they were more accurate in producing stops and nasals compared to other consonants [24]. Gaul Bouchard et al. investigated French-speaking children after implantation and showed that stops and labials (/m/, and /b/) were the predominant class of consonants throughout the study [25]. In the present study, NH children showed the lowest accuracy in producing /r/ and /ʧ/, while children with CI were less accurate in producing /q/, /x/, /ʤ/, /l/, /j/, and /r/. This supports the results of previous findings. For example, Ertmer and Goffman compared speech production accuracy in young CI recipients and typically developing age-peers. They showed that children with CI had lower scores for 3 and 4 sets of words starting with liquids, affricates, fricatives, and trill [26]. Sundarrajan et al. reported that stops and nasals were the most accurately produced consonants, while affricates were less accurately produced ones [20]. Rahimi et al. compared language skills in CI and NH children aged 5–8 years. They reported that most participants faced more challenges in producing /s/, /z/, /ʧ/, /c/, /g/, and /q/ [27]. These findings demonstrate that for children with CI, it is easier to produce sounds in the anterior part of the roof of the mouth than in the posterior part. Therefore, not only a visual cue plays a pivotal role in correct production of sounds, but also simple motoric features of the sounds have a role in production of sounds by children [28, 29].

In our study, children with CI were not at the same age during surgery and their hearing ages were different. Therefore, we could not compare children in two different age groups. Further studies are recommended to evaluate consonant production skills of children with CI and NH children according to their hearing age. We used a single word test to assess the children's production skills. Since children's speech samples were not enough and speech errors could not be thoroughly analyzed, further research is recommended to investigate production errors in connected speech of children with CI using a larger sample size.

Conclusion

Cochlear implantation plays an important role in speech production skills of children with hearing loss. Although children with CI have lower scores compared to age-matched peers, they have similar learning sounds production skills, even if they had cochlear implantation before age four.

Ethical Considerations

Compliance with ethical guidelines

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Authors' contributions

MS: Study design, data collection, interpretation of the results, statistical analysis, and writing the manuscript; NJ: Study concept, and design, supervision and interpretation of the results, statistical analysis, and final revise.

Conflict of interest

No conflicts of interest are declared by the authors.

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