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Research Article

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Evaluating the Ability to perceive the Pitch in Cochlear Implant users

Nader Saki[1], Soheila Nikakhlagh[*1], Majid Karimi[2], AzarBorjSefidi[3], Hosein Rekabi[4], Mozafar Sarafraz[4], Hossein Bagheripour[3], Amir Ahmadi[3] and Ali Yadollahpour[5]

[1]*Associate Professor of Otolaryngology, Hearing and Speech Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*
[2]*MS in Audiology, Khuzestan Cochlear Implant Center, Ahvaz, Iran*
[3]*Khuzestan Cochlear Implant Center, Ahvaz, Iran*
[4]*Associate Professor of Otolaryngology, School of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*
[5]*Assistant Professor of Medical Physics, Department of Medical Physics, School of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*
**Email: nikakhlagh.s@gmail.com*

ABSTRACT

Pitch perceptionis the most important factor in perception of phonetic and prosodic features of speech. The difference limen for frequency (DLF) is the index of ability to percept the pitch. The purpose of this study was to examine the ability of people with cochlear implant in pitch perception at the frequencies of 500, 1000, 2000 and 4000 Hz and to compare it with normal healthy counterparts. In this cross-sectional study, DLF test was conducted on 17 normal individuals with an average age of 32.76 ± 6.5 years old and 9 individuals with cochlear implant with an average age of 31.77 ± 6.6 years old who had hearing loss after speech training. After a period of speech training (on average 8 sessions), DLF test was repeated for people with cochlear implant. Data were analyzed with statistical package SPSS using Paired t-test and independent variables tests. In the initial test, the DLF in individuals with cochlear implant in all experimental frequencies was significantly higher than normal people (p <0.05). Considerable improvement was observed in the level of difference limen for frequency of people with cochlear implant after training course (p <0.05).The findings of this study show that people with cochlear implant have partially ability to understand the pitch, especially at low frequencies and this ability improves with regular training.

Keywords: cochlear implants, Pitch Perception, Difference limen for frequency, Hearing Improvement

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INTRODUCTION

Speech perception is a delicate chain of events including sensory stimulus to electrical signals in the receiver level, the transmission of these signals through peripheral nerves and processing and interpreting them in central nervous system. Any abnormalities in this process can dramatically affect the perception(1, 2). In this regard, the role of peripheral and central auditory system disorders in speech perception the consequences have been studied extensively. For example, inner ear damage or auditory nerve can decrease the hearing threshold as well as the abnormal processing of severity, frequency and time of sound (3, 4). In addition, central nervous system damage leads to complex processing defects in speech perception and recognition of sound (5, 6). During the recent years using biomarkers for predicting disease progression or predicting treatment response has been dramatically developed.

The pitch perception or perception of changes related to frequency information is very important because they carry prosodic information(1, 2) with different applications for example, using this information we can distinguish the emotional state of the speaker, or distinguishing predicative sentences from question sentences. Also frequency information is the carrier of acoustic / phonetic information including formant transmission that is used for difference of vowels as well as syllables of vowel - consonant (7, 8).

Psychoacoustics study is human subjective perception of sounds. In fact, the Psychoacoustics relates physical properties of sound to feeling and perception arisen from it(9). Frequency is one of the main features of sound that is often investigated in psychoacoustics studies. Difference limen for frequency (DLF) is used in order to examine the ability to understand pitch.Lowest frequency differences between the two sounds that ear understand it is called difference limen for frequency. Difference limen for frequency that is shown by Δf is the lowest noticeable difference between the frequencies of two sounds with frequency of f and f + fΔ(9, 10). The amount of DLF in normal people in pure sound stimulus is changed in proportion to stimulus frequency, so that DLF is increased by the increase of frequency. Also in a fixed frequency difference, the lowest identifiable frequency is affected by stimulus intensity level, and would be reduced by its increase(9, 11). The DLF indicates the accuracy of representation of frequency features of acoustic stimulus in hearing system. In other words, the ability to distinguish the frequency difference in normal range indicates audio information encoding in frequency dimension by the auditory system had the highest accuracy.

In addition, comparing DLF between two normal and damaged hearing devices yields valuable information on the reduced accuracy in audio encoding induced by damage in hearing system. Analysis of DLF along with the evaluation of other hearing cognition and electrophysiological functions can shed more light into the nature and extent of the damage (8).Therefore, regarding to the importance of the issue, many researchers have studied and investigated on the acquisition of extents of the norm of these indices as well as their changes in pathologies and different conditions, including Clinard and colleagues in 2010 obtained the DLF in the two frequencies of 500 and 1000 Hz for 32 persons in age of 22-27 years old with normal hearing (dBHL25≥ in octave frequencies of 250-8000 Hz), and observed a significant decrease in DLF in both frequencies of 500 and 1000 Hz with increasing age(12). Considering that the peripheral part of auditory system is the main way of transmitting information. Disorder created in this level may have a significant impact on auditory processing abilities, including ability to understand pitch. As expected cochlear implant compensates the peripheral part of auditory system, the aim of this study is to investigate the ability to understand pitch in people with cochlear implant using DLF test and comparing it with normal people.

MATERIALS AND METHODS

In this cross-sectional study, DLF test was conducted on 17 normal individuals with an average age of 32.76 ± 6.5 years old and 9 individuals with cochlear implant with an average age of 31.77 ± 6.6 years old who were hearing loss after language learning. To carry out the investigation, at first the patients with cochlear implant with Advance Bionic Prosthesis and their concomitants referred to Cochlear Implant center in Ahvaz were invited to collaborate on project, and enough information about the method and the results of this test were at one's disposal. Following the receiving the written consent, the first history-taking was conducted from each individual to identify and exclude any ear disease history and confounding factors. During the implementation of this step, the demographic data of each patient were colect6ed and exclusion and inclusion criteria were applied. In addition, the level of pain and status and amount of discharge from the ear were asked from the patient. Then, the patient was examined by autoscopic examination. If there is no foreign body in ear canal and having norm tympanic membrane, tympanometry test in both ears was done using an audiometer immittance device, model of Zodiac 901 manufactured by Madsen to exclude middle ear disorders. If the tympanometry tests showed the tympanometric peak pressure within the range of -100 to +50 daPa and static compliance of 0.3 to 1.6, the subjects were assigned in the normal group. Then, aerial thresholds were determined in frequencies of 250 to 8000 Hz using two-channel audiometer device, model of AC 40 manufactured by Interaucostic Co. in acoustic room. Then, the DLF test with pure tone stimulus at frequencies of 500, 1000, 2000 and 4000 Hz was done for both normal and cochlear implant groups. The implementation process of DLF test was so that in listening comfort level, a sound with frequency of 1000 Hz with specific frequency changes according to percentage was presented to the individual intermittently through the speakers and he was asked to answer whether the sound has been heard is monotonous or pulsating. If the sound was heard pulsating, percentage of changes in frequency was reduced to the extents that sound to be heard monotonous. If the person heard the initial sound in terms of monotonous, percentage of changes in frequency was increased to the extents that sound to be heard pulsating. The minimum frequency changes based on percentage that was necessary that the two sound to be heard pulsating by the person was considered DLF. This action was repeated for other frequencies. The test was conducted in acoustic room. After a training course (averaged 8 sessions), DELF test was repeated for people with cochlear implant. Data were analyzed by independent and paired t-tests using SPSS version 18statistical package.

RESULTS

Patient characteristics are presented in Table 1. The values of DLF of normal hearing people and those with cochlear implant in the initial test are presented in Table 2. Table 3 shows the DLF for people with cochlear implant in the initial test and after training course.

Statistical analyses showed that in the initial test, the amount of difference limen for frequency in people with cochlear implant in all experimental frequencies was significantly higher than normal group ($p < 0.05$). In addition, a considerable improvement was observed in the difference limen for frequency of people with cochlear implant after the training course compared to the initial test ($p < 0.05$).

Table 1.Characteristics of the patients

Type of prosthesis	Laterality	age	Item
Advance Bionic	Right	23	1
Advance Bionic	Right	25	2
Advance Bionic	Left	31	3
Advance Bionic	Right	43	4
Advance Bionic	Right	29	5
Advance Bionic	Right	36	6
Advance Bionic	Left	27	7
Advance Bionic	Right	33	8
Advance Bionic	Right	39	9

Table 2. Values of difference limen for frequency in Hz in normal people and those with cochlear implants in initial

Frequency	DLF in controls	DLF in CIs	P- value
500	2.08	4.04	P=0.001
1000	3.11	6.33	P=0.001
2000	4.92	19.67	P=0.001
4000	21.43	56.41	P=0.001

Table 3. Values of difference limen for frequency in Hz in people with cochlear implants in initial test and after training course

Frequency	DLF in CIs (initial)	DLF in CIs (after training)	P- value
500	404.	2.72	P=0.001
1000	6.33	4.91	P=0.001
2000	719.6	13.27	P=0.001
4000	56.41	41.30	P=0.001

DISCUSSION

The aim of this study was to evaluate the ability to understand pitch in people with cochlear implant by using the DLF test and compare it with people with normal hearing. Findings of this study showed that in both groups of people with normal hearing and those with cochlear implants, the amount of DLF test was significantly increase with increasing frequency. This finding is consistent with other studies such as Propst et al. (2002). People with cochlear implant are able to distinguish frequency so values obtained from these people had significant difference values with values of people with normal hearing. This ability improves with regular training.In people with normal hearing, different spatial variation of basement membrane by increasing the rigidity of the membrane from the base to the apex the possibility of allows encoding for different frequencies and the ways of hearing maintain this regular frequency balance(2,17). While, in people with cochlear implant of electrical stimulation can directly stimulate nerve fibers. Therefore, the participants with cochlear implant for frequency encrypted should rely on computer processing strategies.Therefore, encoding of these people may be less than desirable limit. In addition, people with cochlear implant sound encoding depend mainly on the spatial pattern and the number of electrode channels(5,16). These factors along with the destruction spiral complex in the effect of hearing and also possible damages caused by the insertion of electrode can also explain the poor performance of people with cochlear implant compared to normal subjects in signal pitch distinction(13-15).

CONCLUSION

Findings of this study show that people with cochlear implant have ability to partially percept pitch, especially at low frequencies and this ability improves with regular training.

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