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Modeling of cochlear implants with different frequency ranges by means of spectrally deprived speech

Abstract

Basics: In the Medel cochlear implant a frequency range can be set from 70-350Hz up to 3500- 8500Hz. It is necessary to find the best frequency range for CI speech perception. Earlier we showed that comb filtered speech (spectrally deprived speech) can be used in modeling of CI speech perception.We carried out this study of the comb filtered speech recognition in four frequency ranges.

Methodics: In our study we used five 50Hz bands from four frequency ranges from the lower limit 70Hz to the upper limit 8500Hz. We used model of 5-channel implants. 9 normally hearing listeners took part in this study.

Results and discussion: The best result ofcomb filtered words recognition was in the frequency range 250-6500Hz, minimal recognition in the broadest frequency range. The difference was significant in accordance with the Student test($p < 0.05$). The individual results of the words intelligibility in the frequency range 250-6500Hz are in range 56-92 %/ Results of study help to audiologist in conversation with parents of CI patients.

Keywords: cochlear implantation, ci model, ci frequency range, comb filtration, spectrally deprived speech

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Introduction

In the Medel cochlear implant a frequency range can be set from 70-350 Hz up to3500- 8500 Hz. It is logical to assume that there is best frequency range for speech perception.

Previously we had performed a research of perception of speech processed by the comb filter. We used speech signal with mosaically deleted parts of the spectrum (spectrally deprived), which was represented by several narrow bands in the frequency range 250-\6250 Hz.[1,2] It was found that there are parallels between the speech perception of implanted patients and the perception of spectrally deprived speech by subjects with normal hearing. There is possibility to demonstrate difficulties of CI user's speech perception to normal hearing subjects using comb filtered speech.

So this method can be used as model of CI. Based on these parallels, we conducted the present study.

The aim of the study is to investigate the intelligibility of spectrally deprived speech depending on the width of their frequency range.

Material and methods

In our study.[1] it was shown that the maximum intelligibility of speech represented by 5 bands of 50Hz width, distributed in the frequency range 250-6250 Hz, was 90%, i.e. the spectral redundancy of such a speech signal is equal to zero. Based on this result, in this study we used 5 bands of 50Hz width in four frequency ranges.

We used 4 frequency ranges: 350-6500, 250-6500, 250-8500 and 70-8500Hz. In the fitting program "Maestro" we established these frequency ranges of 12-channel implants and recorded values of the central frequencies of the first and twelfth channels of four implants (Table 1). In our study these values were taken as the central frequencies of the first and fifth channels of our models of 5-channels implant.

Further, according to the formula Hartmann[3] the values of three frequencies were calculated, so that the coordinates of the peaks of the oscillations of the basilar membrane corresponding to these frequencies and the central frequencies of the first and 12-th channels of 12-channel implant in every frequency band, would placed at equal distance from each other. After "insertion" of such 5-channel implants into cochlea the central frequencies will lies in accordance with the tonotopical organization of cochlea in four implants of every frequency range.

In Table 1 there are values of five frequencies, equally spaced in distance along the basilar membrane in four implants with four frequency ranges.

The process of comb filtering involves dividing the speech signal into spectral bands that can be selectively removed by the experimenter to leave a signal that includes only a small number of narrow frequency bands. As a result of processing according to the program comb filtering "LOR",[4] we received a speech signals, which were represented by five equidistant of 50Hz bands on the basilar membrane in four frequency ranges. Equidistant on the basilar membrane distribution spectral bands in accordance with normal tonotopical organization of the cochlea was chosen by analogy with equal distances between the electrodes in the chain of the implant, i.e. the speech bands were arranged around the central frequencies of the five-channel implants, operating in four different frequency ranges.

In the following Figure1 there is an example of a spectrogram of speech signals used in the present study.

Subjects

9 adult participants, 5 males and 3 females, aged from 22 to 31 years old took part in this study. All subjects had hearing thresholds of 10 dB HL or better across the frequency range 250 – 8000 Hz and normal middle ear function bilaterally, as assessed using an

audiometer-impedance meter (Type AA220). All participants were native Russian speakers, unfamiliar with the test materials and had no prior experience with the processed speech used in the study.

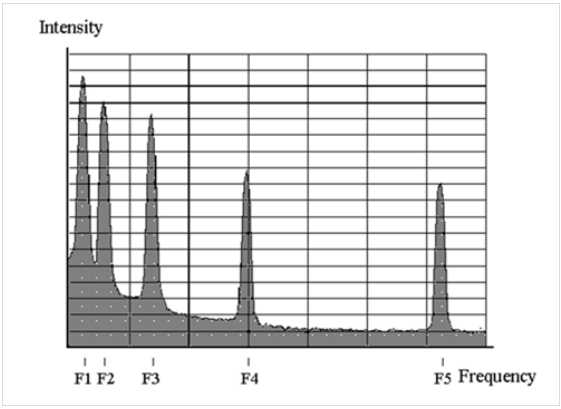

Figure 1 The example of a spectrogram of the spectrally deprived speech signal.

The test material for comb filtration was a standard set of word lists (30 words per list) as used in routine speech audiometry, according to accepted Russian standards (5289-68). The subject established a comfortable loudness, and had to repeat the understood words. Correct answers were recorded. Used phones TDH-39.

The results and their discussion

The averaged results of the measurements of the recognition of the spectrally deprived words depending on the width of their frequency range are presented in Table 2.

As can be seen from the Table 2 the highest intelligibility of words had been detected in the frequency range 250-6500 Hz. The intelligibility of words decreases with the increase of low frequency border up to 350Hz. Also intelligibility decreases with the extension of the range 250-6500Hz in the direction of the high frequencies up to 8500Hz, and in extending the range of 250-8500 in the direction of low frequencies down to 70 Hz. Intelligibility of words in the frequency range 250-6500 by paired Student's test was significantly higher than all the rest. Lets look results of words intelligibility in the frequency range 250-6500Hz.

The individual results of the words intelligibility of the nine subjects in the frequency range 250-6500 Hz are in Table 3.

Table 1 Values of frequencies, equally spaced in distance along the basilar membrane with four frequency ranges, used in our study

Frequency Ranges	Central Frequency of 1st Channel of 12-Channel CI	2nd Frequency of 5-Channel CI	3rd Frequency of 5 Channel CI	4th Frequency of 5 Channel CI	Central Frequency of 12th Channel of 12 Channel CI
350-6500	398	781	1573	3028	5798
250-6500	289	640	1395	2860	5728
250-8500	293	693	1607	3496	7418
70-8500	120	448	1251	3108	7410

Table 2 Recognition of spectrally deprived words depending on the width of their frequency range

Frequency Range, Hz	350-6500	250-6500	250-8500	70-8500
Recognition, %	71	73	64	63
Rms, %	12	12	13	14

Table 3 Words intelligibility of 9 individual subjects. The frequency range is 250-6500 Hz. Subjects are ordered according to their score on the test

Subjects	1	2	3	4	5	6	7	8	9
The intelligibility of words, %	56	60	63	73	73	76	82	86	92

How can we use this results? All subjects are persons with normal hearing, so we can say that from the point of view of their state of the auditory function they were in the same position during the examination. However, as you can see from table 3, they show different results in the perception of processed words. Scatter of results is 36%. This scatter serve for vivid illustration of the different abilities of different people to get used to a new sound picture, i.e. the initial conditions of the psychophysical characteristics of the subjects are the same ones but ability to understand impoverished speech are different one. Without doubts there is a similar diversity of characteristics of patients with cochlear implants in their ability to understand impoverished (implanted) speech.Based on this analogy the audiologist can give an answer to a frequent question from parents: Why do the results of my child's rehabilitation differ (worse) from others?

This study showed that the best of four examined frequency bands for the perception of spectrally deprived speech signal is a frequency range from 250 to 6,500Hz. On the basis of parallels between the speech perception of implanted patients and the perception of spectrally deprived speech by subjects with normal hearing it can be assumed that the maximum frequency range 70-8500 Hz is not the best one for the perception of speech by the patients after cochlear implantation. And a few words about the CI patients who use the frequency range from 70Hz. It should be noted that a FS-4 strategy that is designed specifically for low frequency range has no advantage compared with CIS.[5] It should be emphasized that this study was conducted in the Chinese, where the expected effect of FS-4 had to be displayed more clearly. As for adult CI patients they prefer range 250-6500Hz for speech perception and subjectively they do not distinguish CIS and FS-4 in frequency range 250-6500Hz.

Conclusion

a. The maximum intelligibility of spectrally deprived speech presented by 5 bands of 50Hz width was detected in the frequency range from 250 to 6,500Hz.

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b. The frequency range of the Austrian cochlear implant from 70 to 8,500Hz does not provide maximum speech intelligibility of patients after cochlear implantation.

c. Results of study help to audiologist for explanation of some problems of CI patients to their parents.

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Conflicts of interest

Author declares there are no conflicts of interest.

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