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INVESTIGATION OF SPEECH PERCEPTION FOR PATIENTS WITH A COCHLEAR IMPLANT SUPPORTED WITH A HEARING AID

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The investigations were carried out for 5 listeners with a cochlear implant, 2 male and 3 female at implantation age 13–62 years. The deafness for 4 subjects was recognized as postlingual and for 1 – as perilingual. All listeners were using the hearing aid on the opposite ear to the implant. The speech intelligibility was determined in two cases: when transmission was only via the implant and when the hearing aid was also used. Additionally, the ability of discrimination of male and female voices was performed. The presentation of tests was conducted for three angles (0°, -90° and $+90^\circ$) in relation to the listener's head for the levels equal to 50, 65 and 80 dB SPL. The Polish monosyllabic word tests (PRUSZEWICZ *et al*., [4]) were applied. The improvement of the speech intelligibility was affirmed when the process of hearing via the implant was supported with a hearing aid. The particularly essential differences in the speech intelligibility was observed for angle $+90^\circ$ (HA-side). The results obtained in the investigations show that acoustic compensation in the range of remaining audibility field in a great degree supports electrical hearing.

Key words: cochlear implant, hearing aid, speech intelligibility, discrimination.

1. Introduction

The problem of aural perception acquire a special significance in the case of subjects with a hearing pathology. Contemporary medicine and hearing aid acoustics can offer a number of procedures aimed at compensation of hearing deficiency. For instance, it has become possible to use a hearing aid simultaneously with a cochlear implant or to have partly inserted cochlear implant in the case of deep hypoacousis for the frequency range above 1.5 kHz (losses of the SKI-type). Nevertheless, many adults who receive a unilateral cochlear implant do not continue to use a hearing aid in the non-implanted ear [1]. Among the patients of the Department of Otolaryngology, those using a hearing aid on the non-implanted ear are really a few in number. It seems interesting in view of the fact that the implant is inserted into the ear with greater hearing loss and that the non-implanted ear is usually confirmed to have residual hearing ability. The

reasons for abandonment of the hearing aid include a shift of the reproduction of the sound pitch on the basilar membrane. Investigations on the tonotopy for patients with a cochlear implant and a hearing aid carried out in our department brought to the conclusion that the signals presented via the implant were evaluated as higher relative to the same sounds/signals presented via the hearing aid and that comparison of the signals' pitch is difficult because of a different character of stimulation which causes extremely different acoustical sensation [3]. In spite of differences in aural sensations perceived via a cochlear implant and a hearing aid one can suspect some advantages in using both devices simultaneously.

One of the most important criterion to evaluate the advantage of using both the cochlear implant and hearing aid is based on the tests of speech intelligibility and speech discrimination (recognition). As one of the examples can serve Ching's study which was performed on a group of implanted children who had not worn a hearing aid for at least 3 years and than were gradually reintroduced to hearing aids. The results of tests executed after one month showed that the children could understand the sentences better and recognize consonants better when they used a hearing aid with a cochlear implant compared to a cochlear implant alone [2]. Another experiment, performed by TYLER [6], concerned adult patients who were tested on word and sequence recognition in quiet and noise. Binaural advantage was stated, in a higher degree, when the signal was presented in noise.

The aim of presented investigations was to determine the advantage of supporting the cochlear implant with a hearing aid in the process of speech perception and, what was the most important, to persuade our patients to take advantage of this resolution.

2. Basic information about the operation of a cochlear implant

Modern cochlear implant systems attempt to selectively stimulate small groups of nerve fibres with minimal channel interactions. To achieve this goal, adequate and suitable signal processing strategies had to be developed, and appropriate mapping of signal parameters to subject-specific psycho-electrical stimulation conditions has to be accomplished in order to provide loudness, pitch and timbre perception which mimic those of normal hearing subjects. The electrode array consists of 22 pure platinum electrode bands and 10 stiffening rings on a flexible silicone carrier. All 22 electrodes are connected independently to the receiver/stimulator by individual, insulated platinum-iridium wires. The electrode bands are spaced equally along the distal 16.5 mm of the array. They taper smoothly from 0.6 to 0.4 at the end of the electrode array. The most basal electrode (closest to the round window) is Electrode 1 and the most apical is Electrode 22 [5]. The physical location of stimulation generally does not match completely the frequency range where most of the speech sound energy is concentrated. The conversion procedure, therefore, has to map by mathematical algorithms extracted parameters of the input signals to the place, amplitude and time dimensions of the electrical stimulation signals. Most coding strategies which are used in today's CI processors divide the input signal into a number of logarithmically spaced frequency bands and generate the stimulus signal based on the signal envelopes in these frequency bands.

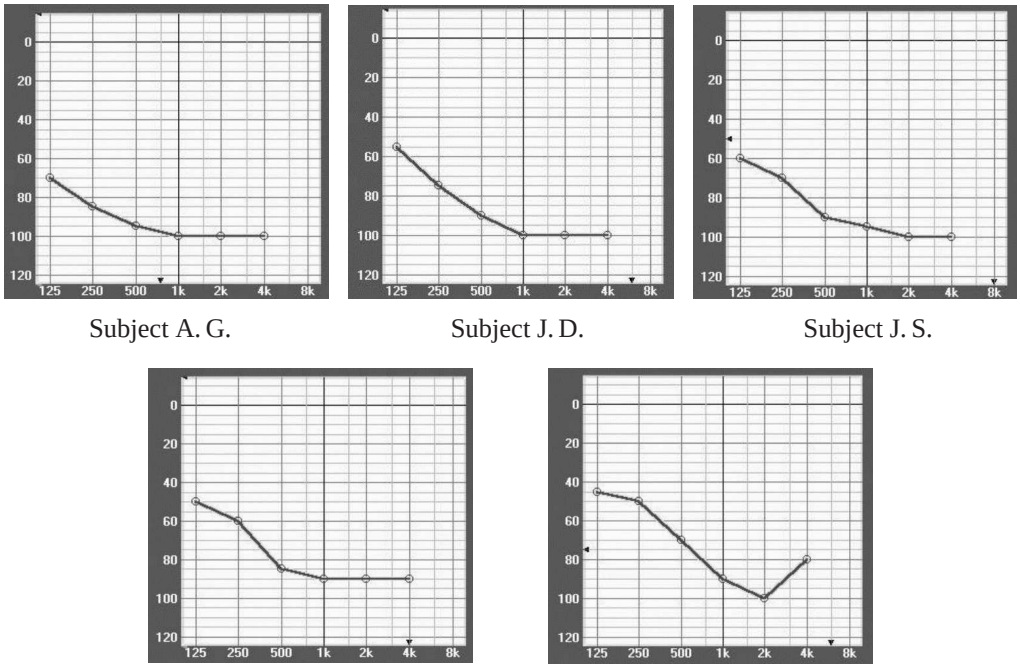
3. Material and method

3.1. Subjects

The subjects were 5 patients aged 13–63 diagnosed with a postlingual deafness (in one case perilingual defness) which means that they mastered speech to the degree allowing full communication prior to the loss of hearing. They were users of cochlear implants type Nucleus 24 and analog hearing aids. The hearing memory acquired prior to the loss of hearing permitted reliable assessment of hearing sensations generated via direct electric stimulation of the hearing nerve. The data of subjects' group are collected in Table 1.

Table 1. Data of subjects' group.

Subject	Gender	Age	Age of implantation	Aethiology
J. D.	Female	53	50	Progressive loss
A. G.	Male	64	62	Progressive loss
K. J.	Male	24	21	Unknown perilingual deafness
K. W.	Female	33	30	Progressive loss
J. S.	Female	15	13	Meningitis



Subject A. G. Subject J. D. Subject J. S.

Subject K. J. Subject K. W.

Fig. 1. Hearing threshold level in non-implanted ear measured in the free field tonal audiometry.

The hearing threshold levels in non-implanted ear measured in the free field tonal audiometry are shown in Fig. 1.

3.2. Method

The investigations of speech intelligibility was conducted for 3 directions relative to the subject's head:

- in front (0°);
- from the CI-side (-90°);
- from the HA-side $(+90^\circ)$

and for 3 acoustic signal levels: 50, 65 and 80 dB SPL.

The Polish monosyllabic word test, containing 10 lists, was used [4]. For every direction and every signal level one of the randomly chosen list (20 words) was presented to the subject. The number of correctly repeated words determined the speech intelligibility. In the case of K. J. subject, with a deep perilingual hearing deficiency and great pronunciation trouble, the word test was replaced by the digit test.

The investigations of discrimination of the male and female voices were carried out for the signal level equal to 65 dB SPL when the loudspeaker was located in front relative to the subject's head. Twenty words, randomly demonstrated by male or female voice were presented to all subjects.

4. Results of investigations

The results of investigations of speech intelligibility in the function of direction at different signal levels for four subjects are presented in Figs. 2–4.

As it is seen from presented diagrams, the advantage of using a hearing aid in non-implanted ear occurs for all cases. The improvement in speech intelligibility was stated for all directions and all signal level presentations (mean value 10%). The least essential differences was observed for the cases when presentation was from direction -90° (CI-side) and the mean value was approx. 7% and the most significant improvement (15%) was observed for direction $+90^\circ$ (HA-side), independently of the signal level presentation.

The results of discrimination tests showed that the advantage of supporting the cochlear implant with the hearing aid achieves approx. 27–28%, independently of subject's gender.

Subject K. J., as it was stated above, was treated individually. Authors had many troubles with performing full experiment for speech intelligibility. Due to the digit test (3 times repeated) the results obtained for 80 dB signal level generally confirmed the advantage of using the hearing aid. However, in the experiment of discrimination of voices, the answers were enough satisfactory to complete the test.

The results of investigation of male and female voices discrimination are presented in Fig. 5.

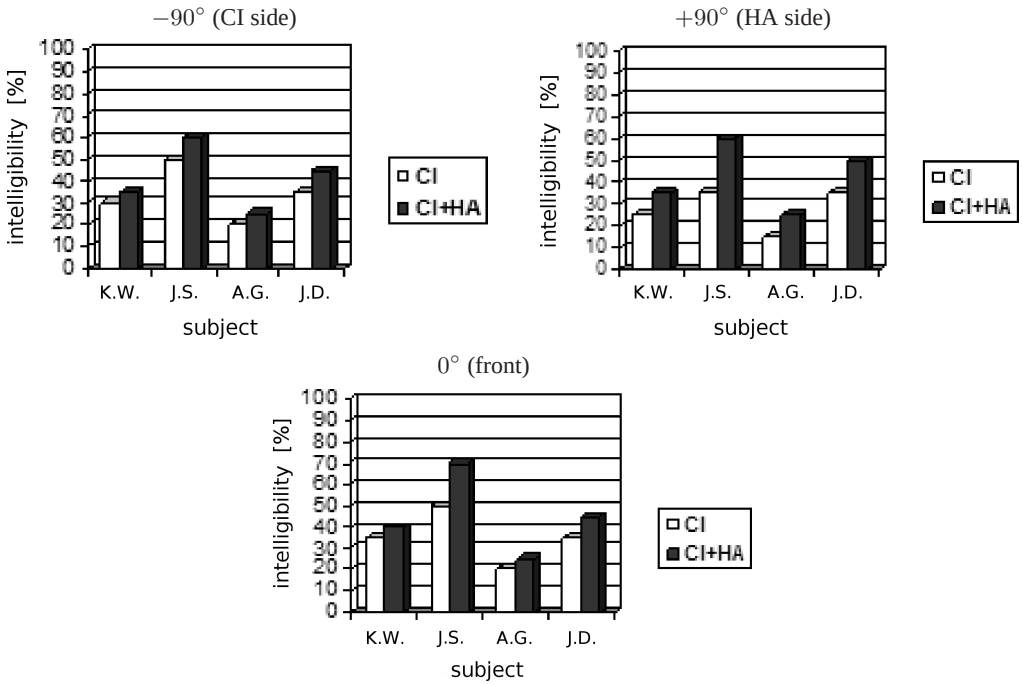


Fig. 2. Speech intelligibility in the function of direction at the signal level 50 dB SPL.

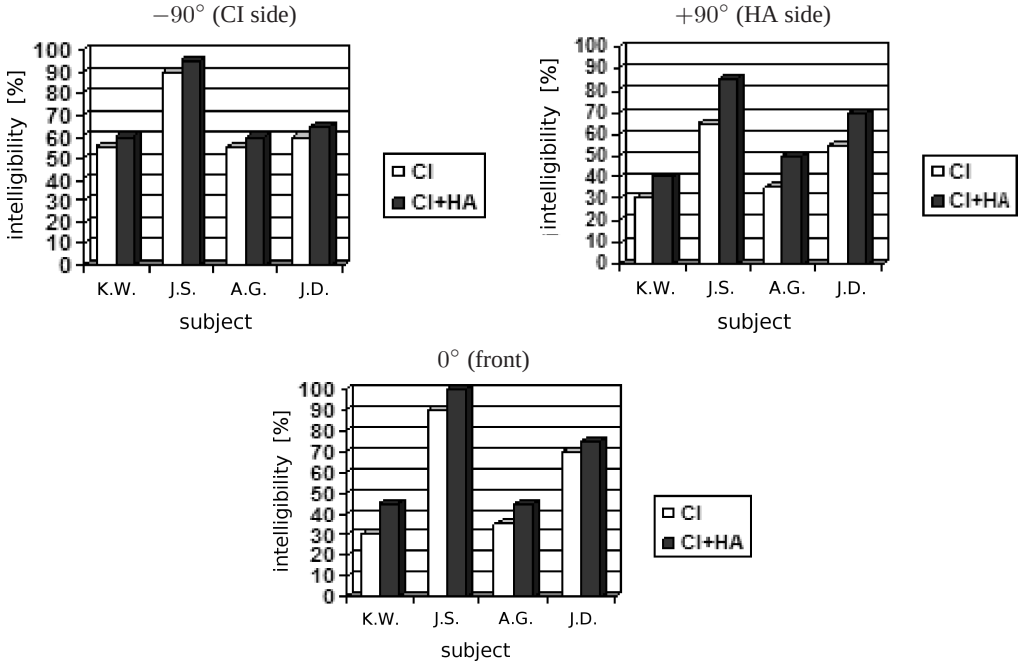


Fig. 3. Speech intelligibility in the function of direction at the signal level 65 dB SPL.

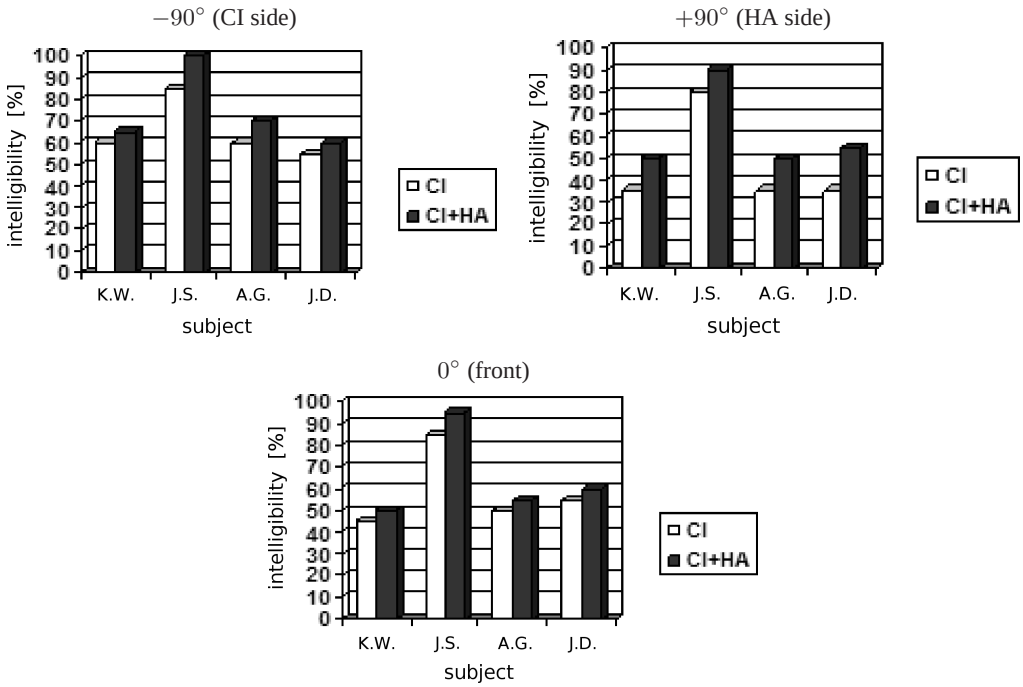


Fig. 4. Speech intelligibility in the function of direction at the signal level 80 dB SPL.

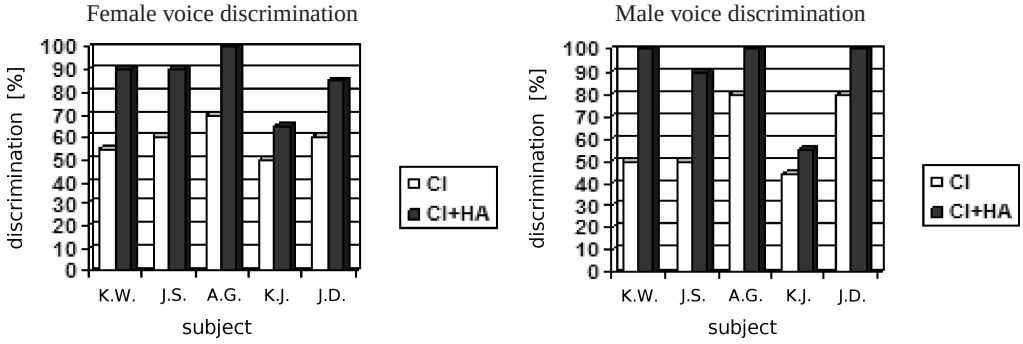


Fig. 5. Discrimination of male and female voices.

5. Conclusions

- Results obtained in the investigations show that acoustic compensation in the range of remaining audibility field in a great degree supports electrical hearing.
- The use of the hearing aid in the non-implanted ear in a great degree improves speech intelligibility independently on the signal level.
- The most significant advantage is observed when the signal presentation was executed from the non-implanted ear direction.

- Significantly great improvement in discrimination of male and female voices is noticed when the cochlear implant is supported with the hearing aid in the contralateral ear.

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