Dorota Hojan-Jezierska¹, Ewa Skrodzka²

Fitting of hearing aids with different technical parameters to a patient with dead regions

¹Department of Biophysics, Poznan University of Medical Science, Poznan, Poland

²Institute of Acoustics, A. Mickiewicz University Poznan, Poland
e-mail: agamon63@wp.pl

The purpose of the study was to determine an optimal hearing aid fitting procedure for a patient with well diagnosed high-frequency 'dead regions' in both cochleas. The patient reported non-symmetrical hearing problems of sensorineural origin. For binaural amplification two similar independent hearing aids were used as well as a pair of dependent devices with an ear-to-ear function. Two fitting methods were used: DSLi/o and NAL-NL1, and four different strategies of fitting were tested: the initial fitting based on the DSLi/o or NAL-NL1 method with necessary loudness corrections, the second fitting taking into account all the available functions of hearing instruments, the third fitting (based on the second one) but with significantly reduced amplification well above one octave of frequency inside dead region, and the final fitting with significantly reduced gain slightly below one octave inside dead regions. The results of hearing aids fitting were assessed using an APHAB procedure.

Key words: cochlear dead regions, hearing aid fitting.

Introduction

A cochlear dead region is defined as a region in the cochlea where inner hair cells (IHCs) and/or neurons are functioning so poorly that a tone producing peak vibration in that region is detected by off-place listening [7-8]. The majority of dead zones are high-frequency dead regions. A frequency limit of the dead region is defined in terms of the characteristic frequencies of the IHCs and/or neurons immediately adjacent to this region (off-place listening). Thus, it is impossible to determine from a pure tonal

audiogram the presence of a dead region, and other methods, like psychophysical tuning curves or a TEN test, must be used [6]. Effects of dead regions on speech intelligibility were reported by Vickers et al. [9] and Baer et al. [1]. For adults with high-frequency dead regions, there is little or no benefit to speech discrimination from amplifying frequencies well inside a dead region, but there may be some benefit (not only in intelligibility of speech) by amplifying frequencies up to 50-100% above the estimated edge frequency of the dead region. For patients without high-frequency dead regions, amplification of high frequencies is usually beneficial. In our previous report [5], we dealt with a patient with a vast dead region, with frequency limits impossible to measure, using a standard TEN test because of profound hearing loss and equipment limits. In the above report we presented a simplified version of the experiment reported in the present paper: DSLi/o was the only hearing aid fitting procedure and only two fitting strategies were used: initial fitting and the final fitting. We came to conclusions of a very general nature: the final fitting of a hearing aid was always desirable and a modern, technically advanced hearing instrument seemed to be more helpful than those less sophisticated. In the present paper, we present an extended version of the experiment described in [5] for a patient with well defined dead regions in both cochleas. In our opinion this case is more general.

The aims of our study were:

- to check which type of modern hearing instruments is more beneficial for the following case of a dead region: two independent, similar hearing aids or a pair of dependent devices with an ear-to-ear function,
- to subjectively assess problems and benefits associated with wearing of a hearing aid using the ABHAP questionnaire [3].

Patient, hearing instruments and the method

Our patient was a 30-year old woman, with dead regions in both cochleas. The tonal audiogram of the subject and the results of the TEN test are shown in Figure 1.

The hearing loss shown in Figure 1 is severe. It is a result of treatment using ototoxic medicines in early childhood. A method for the dead region diagnosis was that of the Threshold Equalizing Noise (TEN) [6]. In the right ear, the dead region began at about 4 kHz, and in the left ear at about 1 kHz.

Two pairs of digital hearing instruments were used: a pair denoted H1 (digital, programmable, 12 frequency channels, an acoustic feedback reduction system, an

Figure 1. Tonal audiogram in dB SPL and results of the TEN test

adaptive noise reduction system in 12 channels, 4 compression channels, an adaptive system of directional microphones) and a H2 pair (the same as H1 but with ear-to-ear function)*. The subject was not informed about the price and specific technical parameters of the fitted instruments.

The first initial fitting method was that of DSLi/o [2]. This method is based on a tonal audiogram and does not take into account the presence of a dead region. The second method was that of NAL-NL1 [4]. This latter method is also based on a tonal audiogram and also fails to include the presence of the dead region. However, it takes into account the general well known fact that people with high-frequency hearing loss gain progressively less benefit from amplification of high frequencies as the hearing loss increases. It should be noted that at the present moment there is no popular and faithful fitting formula incorporating the existence of a dead zone [5]. Four fitting strategies were used for each of the two fitting methods. In the first (initial) method it was DSLi/o or NAL-NL1, and only some loudness adjustment was allowed. In the second strategy, the hearing instrument gain was adjusted using all its available features to obtain subjectively assessed maximum of speech intelligibility and comfort. In the third fitting (based on the second one), amplification was significantly reduced well above one octave

* H1 – Siemens Artis SP, H2 – Siemens Artis e2e

of frequency inside the dead region. In the final fitting, gain was significantly reduced slightly below one octave inside dead regions. Two pairs of hearing instruments with a given fitting strategy were tested over two weeks period.

Subjective hearing aid performance was measured using the Abbreviated Profile of Hearing Aid Benefit (APHAB) [3]. The APHAB is a 24-item questionnaire consisting of four subscales: Ease of Communication (EC), Reverberation (RV), Background Noise (BN), and Aversiveness (AV). These subscales assess the benefit derived from the use of a hearing aid with respect to communication under ideal listening conditions (low noise/reverberation with visual cues available), communication under quiet, but poor listening conditions (e.g., reverberation, soft speech, and visual cues unavailable), communication in noisy situations, and negative reactions to environmental sounds. The APHAB test was completed after every 2-week period of experiment. Each time questions were asked for situations with and without amplification.

Results and discussion

Figure 2 shows examples of predicted insertion gains for the left ear for four tested fitting strategies, and for the input sound pressure level of 65 dB (average level of speech) for hearing instruments H1 and H2. Similar gain curves were obtained for the right ear (not shown in this paper).

It can be noted that the initial DSLi/o or NAL-NL1 fitting method was not optimal, and further adjustment of the instruments was always necessary. After initial fitting insertion, the gain was always underestimated in low frequencies and overestimated in the high frequency range. For instruments H2 and the NAL-NL1 method, the initial fitting was completely different from the gains predicted by other strategies. For strategies 2-4, the gain curves did not differ excessively from each other: they were significantly limited in the frequency domain and they required very serious changes in amplification parameters when compared to initial settings (Figure 2b). For instruments H1 and the DSLi/o method, the gain curves for strategies 1-2 were identical (no changes), and they were rather similar to the curve for strategy 3. The insertion gain for the final fitting was significantly lower in frequency when compared to curves 1-3 (Figure 2a). Differences in the insertion gain for the final fitting are presented in Figure 3.

Figure 2. Examples of predicted insertion gains for the left ear: a) H1, DSL i/o method, 1 – initial and second fitting, 2 – third fitting, 3 – final fitting; b) H2, NAL-NL1 method, 1 – initial fitting, 2 – second fitting, 3 – third fitting, 4 – final fitting

It can easily be seen from Figure 3 that the NAL-NL1 fitting method reduced the frequency range of amplification to about 2 kHz (one octave above the low frequency limit of the dead region) for both H1 and H2 sets, while DSLi/o predicted some amount of amplification in the higher frequency range, even with amplification in this range reduced to zero.

Figure 4 presents the results of the APHAB test. The APHAB questionnaire was administered in a computer-and-mouse format. In cases where an item was not applicable, the subject was instructed to make an estimation of how well she thought she would understand speech, or how aversive sounds might have been perceived in this situation. The benefit was calculated by comparing the patient's reported difficulty in an unaided condition with their degree of difficulty when using amplification.

It can be seen from Figure 4 that the smallest number of problems and the greatest benefit was reported after final fitting in almost all cases. The greatest benefit was achieved for EC and RV categories. For the BN category, the benefit was significantly smaller. The assessed percentage of problems (difficulties expressed as percentage) and

Figure 3. Comparison of insertion gains for final fitting: 1 – H1, NAL-NL1; 2 – H2, NAL-NL1; 3 – H2, DSLi/o; 4 – H1, DSLi/o

the benefit in the AV category was very small, except for the case of the H1 final fitting and the DSLi/o method. Instruments H1 with the DSLi/o method were tested as the first ones in the experiment, and we think that the subject was shocked by the sound she had not heard before (the benefit had a negative value, i.e. the worse perception in the AV category compared with the unaided condition). Subjective assessment of amplification was made only once after each testing time. The assessment of the unaided condition was made after every 2-week period of testing. Thus, we were not able to find standard deviation for an amplified condition, but we were able to calculate it for the unaided condition, and we found it to be about 11. Therefore, we took this value as a standard

Figure 4a. Results of APHAB (assessment for amplification in both ears)

Figure 4b. Results of APHAB (assessment for amplification in both ears)

deviation for the difficulties expressed in percentage for amplification. In the light of this assumption, the greatest absolute benefit after final fitting was that in the EC, RV and BN categories for a pair of hearing aids denoted as H1 and for the DSLi/o method. When we compared this result of APHAB with the insertion gain for the final fitting of H1 with the DSLi/o fitting method (Figures 2a and 3) we noted that the best result of speech understanding in quiet and noisy acoustic environment was obtained for the gain of a rather medium value and limited in the frequency to about one octave above the low frequency limit of the dead region. For the remaining fitting strategies, both fitting methods and both pairs of hearing instruments had the difficulties expressed in percentage and the benefit comparable (Figure 4).

The pair of hearing aids denoted as H1 was one without ear-to-ear function. It is perhaps too much to conclude that this kind of hearing instruments is a better choice for patients with dead regions. We would, however, like to point out that for our patient this was the best solution. What is more, the benefit of 100% does not mean that the speech intelligibility is also 100%. It only means that with the maximum benefit the speech perception is the best possible.

Conclusions

From the analysis of the data collected in our experiment in a patient with well defined frequency limits of the dead region in both ears we conclude that:

- final fitting is always necessary, and every case of a dead region needs special care and attention,
- limitation of the frequency range of amplification to no more than one octave above a low frequency limit of a dead region was always desirable, and was beneficial to speech intelligibility and some aspects of acoustic comfort and life quality,
- a pair of independent hearing aids (without ear-to-ear function) using the DSLi/o fitting method was more beneficial than a pair of instruments with ear-to-ear function and the DSLi/o or NAL-NL1 fitting method.

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