

Acoustically elicited stapedial reflex in cochlear implanted patients

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Abstract

The results of registration of stapedial reflex in a response to electrical stimuli are often used during the fitting process of cochlear implant. Usually, the most comfortable loudness (MCL) levels of the working program are higher than threshold levels of the stapedial reflex. It is interesting to look at the reflex from another point of view, namely, to investigate the stapedial reflex in response to acoustic stimuli of low, medium and high frequencies in a group of seven experienced children who had been using their speech processor for three or more years. It was found that threshold sound pressure levels of the reflex to sound stimuli are within a normal range. The reflex threshold levels were found to underestimate the behavioral MCL values and therefore should be used with caution during the first fitting sessions.

Introduction

The method of registration of the stapedial reflex in a response to electrical stimuli are used in the fitting of cochlear implant. But as a rule, the most comfortable loudness (MCL) levels of the working program are higher than threshold levels of the stapedial reflex [1,2]. It is interesting to look at the reflex from the opposite point of view, namely, to investigate the stapedial reflex on sound stimuli in experienced implanted patients configured optimally. The aim of this study is the investigation of the stapedial reflex in a response to acoustic stimuli of low, medium and high frequencies.

Materials and methods

7 smart implanted patients participated in this study. Age 7-14 years. All patients used the Med-El 12-channel implant "Concerto". They came to the 4th or later fitting session. Everyone had been optimally fitted and everyone deliberately chose a work program from four programs of increasing loudness. On repeated visits, patient working programs were not changed over the past few years. All patients were familiar with the audiologist and participated with interest in the study. The investigation was conducted at working (comfortable) for each patient program which was selected in accordance with our instruction-explanation [3].

Since this is the first study of the stapedial reflex on sound stimuli in implanted patients, the issues of the influence of gender, age, etiology of deafness, side of the operation, etc. are beyond the scope of this study. The main requirements for selecting children to participate in the experiment were: a clear choice of a comfortable program, a desire to cooperate, a normal tympanogram, and the presence of a stapedial reflex. The parameters of the tympanogram (compliance and pressure) in all children were in the normal ranges.

Sine wave stimuli were generated using the "Adobe Audition" program. The parameters of acoustic stimulus were the following: duration is 260 ms; pulse decay time and pulse rise time of stimuli were 5 ms; frequencies were 379, 1123 and 4365 Hz - the central frequencies of the 2nd, 6th and 11th channels of the cochlear implant, respectively.

We used a sequence of 10 stimuli of each frequency. This sequence was created in the "Adobe Audition" program. The intervals between the leading edge of the tone pulses are 1s, intensity levels of sequential pulses are increased with step of 4 dB. The stimuli were amplified by an Azur640A amplifier so the intensity of successive stimuli increased from 70 to 106 dB SPL. Sound pressure levels were calibrated in an artificial ear 4153 of "Bruel&Kjar". Patients listened to stimuli of 106 dB SPL without any negative reaction.

We switched on a speech processor at working program and placed it under the circumaural embouchure of headphone TDH-3 through which we presented a sound stimuli. Antenna of an implant connected to a long wire was placed on the patient's head. The studies were conducted on the optimal program of each child.

Acoustic stapedial reflexes were registered on the contralateral ear using an audiometer-impedance meter AA220 of "Interacoustics". Impedance meter worked in the reflex decay mode. We simultaneously switched on sound stimulation and the reflex decay test of an impedance meter.

As an example, Figure 1 shows the result of one registration of stapedial reflex printed from the impedance audiometer screen.

As can be seen from the figure, the amplitude of stapedial reflex is linearly increasing with the increase of SPL of acoustic stimuli. The threshold level of a stapedial reflex is 94 dB SPL. The maximum amplitude of stapedial reflex was at 106 dB SPL.

It is obvious that the threshold level of the reflex is lower than an electrical MCL level recorded in this channel. The results of all patients were registered in the same manner. The results of registration of the

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stapedial reflex were printed on the printer of the impedance meter, scanned and then transferred into digital form using the program "Grafula".

Results and discussion

The Figure 2 shows the results of measurements of the amplitude of the stapedia reflex depending on the sound pressure level of acoustic stimuli of 1123 Hz frequency in seven implanted patients.

As can be seen from the graphs there is a wide range of individual values of the threshold levels of the stapedia reflex on sound stimuli in the examined patients. The threshold levels of the stapedia reflex are in the range of 81 - 97 dB SPL, the average value is 88.4±5.4 dB SPL. It should be noted that the amplitude of the reflex increases linearly with the increase of the intensity of acoustic stimuli from the threshold levels of reflexes to the maximum values at intensity level of 106 dB SPL. Since the reflex and loudness are connected, this means that loudness of input stimuli increases continuously from the threshold intensity of reflex to 106 dB SPL. At level of sound of 106 dB SPL subjects had no negative reaction to single stimulus of 260 ms duration.

A similar pattern of a wide range of reflex threshold values and a linear increase of the amplitude of reflexes from threshold levels to the maximum SPL of a stimuli is observed in low and high frequency channels too.

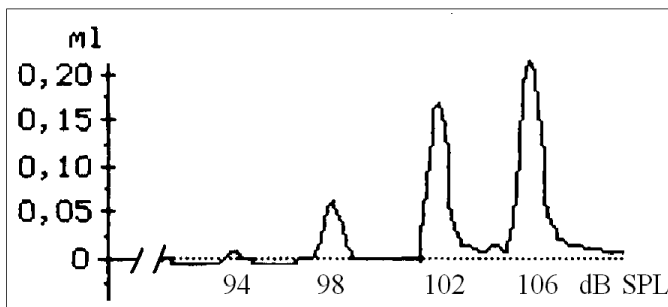


Figure 1. The amplitude of the stapedia reflex depending on the sound pressure level of acoustic stimuli in a patient K. Frequency of stimuli is 1123 Hz. Printout image from the screen of an impedancemeter.

The abscissa axis is the sound pressure level of the stimuli, dB SPL.

The ordinate axis is the compliance of a drum membrane (amplitude of stapedia reflex), ml

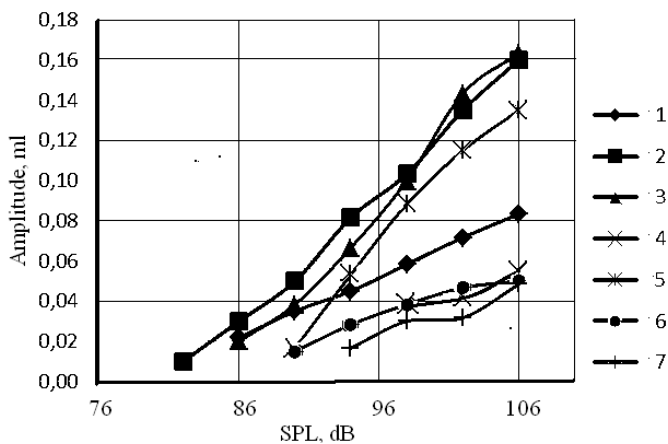


Figure 2. The dependence of the amplitude of the stapedia reflex (ml) on the sound pressure level (dB SPL) of acoustic stimuli of 1123 frequency Hz in seven implanted patients.

The abscissa axis – the sound pressure level of the stimuli, dB SPL.

The ordinate axis – amplitude of the stapedia reflex, ml

Table 1. Ranges of individual results of measurements of threshold levels of stapedia reflex on tone signals of three frequencies and average values of the threshold levels of reflex in three channels of CI

Frequency, Hz	Threshold range, dB	Mean,dB
379	85-101	90.7±6.0
1123	81-97	88.4±5.4
4365	73-85	81.8±4.6

The results of measurements are presented in the Table 1.

The ranges of individual results are similar in all channels - 12-16 dB. Mean values of threshold levels of the stapedia reflex on tonal stimuli of three frequencies in CI patients are located in the range of 81.8 - 90.7 dB SPL. It should be noted that these average values of threshold levels in CI patient coincide with the threshold levels of reflex in subjects with normal hearing. In normal subjects the average values of the threshold levels of the stapedia reflex on tonal stimuli are in the range of 80 to 90 dB SPL [4,5].

It should be noted that reflexes were recorded in all channels of an implants at the working programs of all children. All parents chose the working program from four MAPs recorded in the processor memory. Consequently, all of the MCL levels established in the working programs are above the threshold levels of reflex. Individual results of threshold levels of the stapedia reflex are located in the range from 73 to 101 dB SPL. In normal subjects the individual values of the threshold levels of stapedia reflex on tonal stimuli are in the range of 70-100 dB SPL [6,7].

It is obvious that if the average values of the reflex thresholds in a normal subject are from 80 to 90 dB SPL (Gelfand, 2004) the individual results of the subjects are in a wider intensity range. It means that the threshold levels of stapedia reflexes in CI patients are in the normal range.

As an example, we will discuss the results of measurements in a patient whose threshold level of the stapedia reflex at a frequency of 4365 Hz equals 73 dB SPL. It is obvious that the reflex threshold is registered at the current level much less than the subjectively set MCL level in the working program (further initial program). This child uses 3rd program as working (everyday) one. Parents chose this program in accordance with our explanation-recommendation: "The program is optimal one if your child sometimes hears loud sounds" [3]. This quick-witted child himself said that 4th program was slightly loud one; the 2nd program was a quiet one. A child himself asks to switch on the 3rd program.

Consider what happens if we set the current levels at which the threshold stapedia reflex is registered as MCL level in a new program. In the new program, as well as in the initial, the speech processor will process the input audio signal in the intensity range of 40-106 dB SPL, but the patient's perception will be different than with the initial program.

Naturally, in the new program the reflex will be registered only at the sound level of 106 dB SPL, at 73 dB SPL it will not be, i.e. on the new program at an input signal of 106 dB SPL the patient will hear the same loudness as at 73 dB SPL of the initial program. Consequently, the new program will unnecessarily reduce the maximum loudness achieved at the new MCL level.

Further, if we set the threshold current level in the new program as 10% of the MCL levels, the processor will produce this current level at the trigger level of sound equals to 40 dB SPL, but the signal with this current level will not be heard, because the threshold current in the new program (10% of the new MCL level, equal to the threshold level

of the stapedial reflex) will be below the threshold of audibility. The real threshold of a current audibility is 10% of the MCL levels in the initial program. That is, some part of the sound range that the patient perceived on the initial program will not be heard on the new program. Let's say that in accordance with the output compression function ('maplaw'), the threshold level of the current recorded in the initial program is reached at 45 dB SPL in the new program.

Thus, in the new program, the input sound in the range of 40-106 dB SPL will be heard from 45 dB SPL and 106 dB SPL will be equal in loudness to that the patient heard at 73 dB SPL on the initial program. Clearly quieter than the initial program. Therefore, when setting MCL levels as reflex thresholds levels, there will be an unjustified increase in the threshold of sound perception from 40 to 45 dB SPL and a significant decrease in loudness at a maximum input intensity of 106 dB SPL. It is obvious that such changes will cause loss of input signal information, which will lead to deterioration of speech intelligibility. This is a speculative reasoning which does not require verification. The patient himself, after assessing the perception of speech with a new setting of MCL levels as the threshold levels of reflex, will ask to return the previous setting and will not accept the program with MCL levels equal to the reflex threshold levels. We wrote more about the impact of the threshold and MCL settings earlier [8,9].

Similarly, we can consider the rest of our results. All individual values of the reflex thresholds are in the intensity range from 73 to 101 dB SPL. Therefore, the reflex threshold levels are recorded at SPL less than 106 dB SPL, i.e. threshold current levels of reflexes are less than MCL levels established by the patient subjectively in the working program. Consequently, the threshold levels of the stapedial reflex to electrical stimuli are not used as the MCL levels of the working (optimal) program. A reasoning similar to the above with respect to the threshold level of reflex 73 dB SPL can be applied to all our results obtained by measuring the reflex threshold to a sound.

Our results on the threshold levels of a reflex below MCL levels coincide with many psychoacoustic literature data. For example, in the study of M. Bresnihan "was found that the C-level obtained with ESRs to be consistently lower across all electrodes. Of the 391 measurements made behavioral MCL levels exceeded the threshold levels of reflexes in 380 cases" [1]. Similar results were obtained by us [2] and were confirmed in many other studies.

Based on these studies, we agree with those authors who state that reflex thresholds can be used as a basis for conditioning behavioral responses [10] or that threshold values of stapedial reflexes may usefully assist in programming the CI [11].

An indirect argument against the use of threshold levels of reflex as MCL levels is that almost all of our patients (more than one thousand, with a few exceptions) participated in the SWEEP stimulation-registration of the stapedial reflex without any negative reactions [12].

Answer, please, such question. How can the MCL levels setting being equal to the reflex threshold levels be the final result of the fitting, if the maximum loudness of sound that the patient perceives on the new program is achieved with an input sound intensity of 73 dB SPL at the initial program?

It should be borne in mind that the high correlation between MCL levels and reflex threshold levels is also not an argument in favor of the final MCL levels setting on a level of reflex thresholds. The correlation

coefficient estimates only the direction and strength of the coupling between these parameters but does not give any indication of numerical values as far as the current values of the reflex thresholds are greater or lower than the MCL levels.

In conclusion we can draw some parallels between CI and 1-st stage sensorineural hearing loss of peripheral type:

- Neural origin of hearing losses in both cases
- In both cases a hearing loss is 40 dB
- At 106 dB SPL patients hear loud sounds (near tolerance level)
- The threshold sound pressure levels of the stapedial reflex are within normal limits.
- The perceived loudness of input stimuli is increased linearly from the threshold levels of reflex to 106 dB SPL.

There is possible similarity with the results of Fowler test [13].

With such a combination of features diagnosed in patients with SNHL, the presence of loudness recruitment is observed. We can say that CI patients also have a similar phenomenon.

Conclusions

1. The mean values of the threshold sound pressure levels of the stapedial reflex to acoustic stimuli of three frequencies in implanted patients are in the normal range (81.8 -90.7 dB SPL), and the individual results are in the normal range of 70 - 100 dB SPL.
2. The dependence of the amplitude of the stapedial reflex on the SPL of the sound signal is linear in the range of the intensity of the tonal stimuli from the threshold level of the reflex to 106 dB SPL.
3. The current threshold levels of the stapedial reflex to sound stimuli are below the subjective MCL levels and they cannot be used as the most comfortable loudness levels in the vast majority of implanted patients.

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