Auditory thresholds in patients with cochlear implant: Correlation of ASSR and PTA measurement

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Auditory threshold measurement in the deaf patients with cochlear implant requires active cooperation of tested proband. Subjective methods to measure the auditory threshold cannot be applied in small children and non-cooperating patients. Due to lower and lower age at the time of implantation objective electrophysiological tests must be used to measure the proper function of the implant and to define the auditory threshold. Several methods have been used for this purpose:

1. NRT (neural response telemetry): is a well known and widely used method to run per-operative measurements as well as postoperative testing. Correlation with the T-values in the fitting process is also contribution of this method.
2. EAP(electrically evoked action potential of the auditory nerve) does not correlate with T and C values
3. EABR (electrical auditory brain stem response)
4. ESR (electrical stapedius reflex)

Many authors found out that some of these methods (NRT, EABR) may help to fit the processor properly but there are some limits to define the hearing threshold. Algorithm to identify and detect the response is not exactly defined and subjective reactions of the tested object complement the test results as well as subjective evaluation of investigator. ASSR measurement seems to be very promising method to measure the hearing threshold. Only few papers deal with ASSR measurement after implantation (Ménard 2004, Hofmann 2010, and Yang 2008).

ASSR is a recently developed method that might be used in hearing loss diagnosis as well as in patients after cochlear implantation. The ASSR is an electrophysiologic response evoked by one or more carrier frequencies, simultaneously presented and amplitude- and/or frequency- modulated at a specific frequency. A frequency of modulation entrains the brainwave to produce an essentialy sinusoidal response for each carrier. The generated small signals are extracted from the background noise via a combination of time-ensemble averaging and high-resolution spectral analysis and averaging. Threshold estimation is based upon statistical evaluation of the electrophysiologic response, carried out by the computer, thus making the method entirely objective (Ménard, 2004).

Nowadays there are several systems to measure and evaluate ASSR: a monaural single-frequency technique with a detection method based on phase coherence (AUDERA), and a binaural multiple-frequency technique using the F-test (MASTER). Measurement of the hearing threshold in CI patients can be deteriorated by electrical artefacts. Some papers show that not all of the responses are artefacts and those artefacts can be differentiated from the real electrical responses (Ménard 2004).

ASSR is usually used to define the hearing threshold objectively. There are several papers to compare behavioural hearing threshold in patients with different type of hearing loss with the threshold measured by ASSR (D´Haenens 2009, Swanepoel 2004). In SNHL threshold measured by ASSR correlates with the threshold measured by PTA. It is well known more severe the SNHL is better correlation can be found. The thresholds do not correlate in patients with normal hearing or milde SNHR. More significant differences can be found in patients with conductive hearing loss (Dimitrijevic 2002, Swanepoel 2004, Rance 2002, Swanepoel 2007, Luts 2004, Herdman 2003, Tlumak 2007, and Picton 2005).

Ménard et al. confirmed correlation of the behavioural hearing threshold in patients with CI with the threshold measured by electrically evoked ASSR. Signal was generated by MASTER the nit was fed to an audiometer to control the intensity of the signal. The processor was connected directly to the audiometer, replacing the signal from the microphone (Menard 2004).

The goal of our paper was to find a correlation between subjective hearing thresholds measured in the free field by acoustical stimulation and acoustically evoked ASSR.

Material and Methods

Fifty subjects (27 females and 23 males) in the age 11-78 years (37,8 in average) that use cochlear implant for at least 8 years were tested by both methods. All of them were experienced CI user with reliably detected hearing threshold.

The first test was measuring of the hearing threshold with CI in free field condition. The warble tone was delivered by the loudspeaker placed in front of the proband in the distance 1,5m without any background noise. The hearing threshold was measured in the frequencies 500, 100, 2000 and 4000 Hz.

Measurement of objective hearing threshold was done in frequencies 500, 100, 2000 and 4000 Hz by the device Chartr EP (GN Otometrics) that uses method of algorithm analysis FLC (adaptive filtering algorithm Fourier Linear Combiner). Air conduction via the head set loudspeaker was used to stimulate cochlear implant. The stimuli were compound of four carrier frequencies 500, 1000, 2000 a 4000 Hz, with amplitude modulation 80 and 90% and frequency modulation 25%. Surface electrodes were placed in the standard mode with impedance less than 3kΩ (Fig. 1). The speech processor was switched on in the mode most frequently used by the patient. Measurement was done in the sound proof room, in relaxed laying position.

Active (+) Electrode :
Cz or Fz - Vertex or high forehead (yellow)
Cz or Fz - Vertex or high forehead (white)
Reference (-) Electrode
Left mastoid (blue)
Right mastoid (red)
Ground Electrode (black)

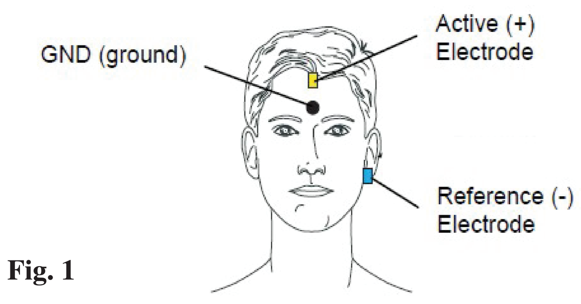
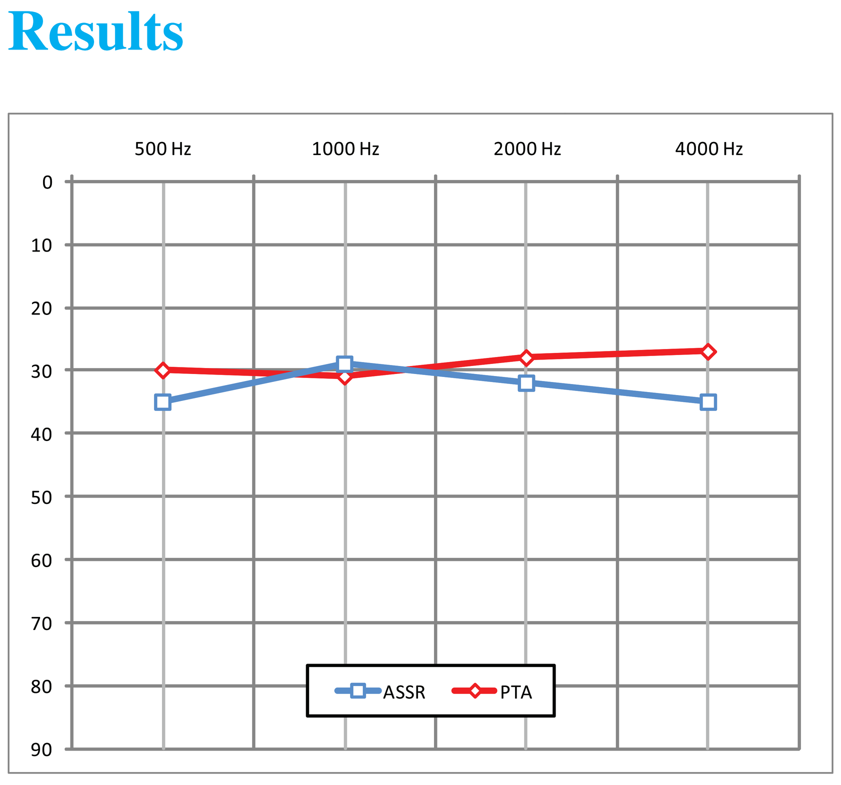


Fig. 1

Statistical analysis:

For each frequency (500 Hz, 1 kHz, 2 kHz, 4 kHz) we calculated Pearson's correlation coefficient, the test the null hypothesis that the true correlation coefficient is 0 and t-test for paired samples.

Results



The average thresholds measured by the two above mentioned methods in the frequencies 500, 1000, 2000 a 4000 Hz are presented in the figure 2. The blue curve illustrates the average threshold in free field condition (34dB for 500Hz, 27 for 1000, 30 for 2000 and 33 for 4000) while red curve illustrates threshold measured by acoustically evoked ASSR (31dB for 500Hz, 32 for 1000, 29 for 2000 and 29 for 4000) .

Fig. 2.
The average hearing threshold in patients with CI measured by warble tone in free field condition (blue curve) and acoustically evoked ASSR (red curve).

Correlation				
Frequency	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Correlation coefficient	0,279	0,24	0,016	0,124
p-value	0,049	0,09	0,91	0,39
statistically significant correlation	yes	no	no	no
Dependent t-test for paired samples				
Frequency	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
p-value	0,01	0,35	0,04	0,001
Statistically significant difference	yes	no	yes	yes

Table 1.

Statistically significant correlation was confirmed only in the frequency 500Hz. In the frequency 1000Hz there was no statistically significant difference between the two measurements (Table 1,2,3,4,5). There was no significant correlation in frequencies 2000 and 4000 Hz.

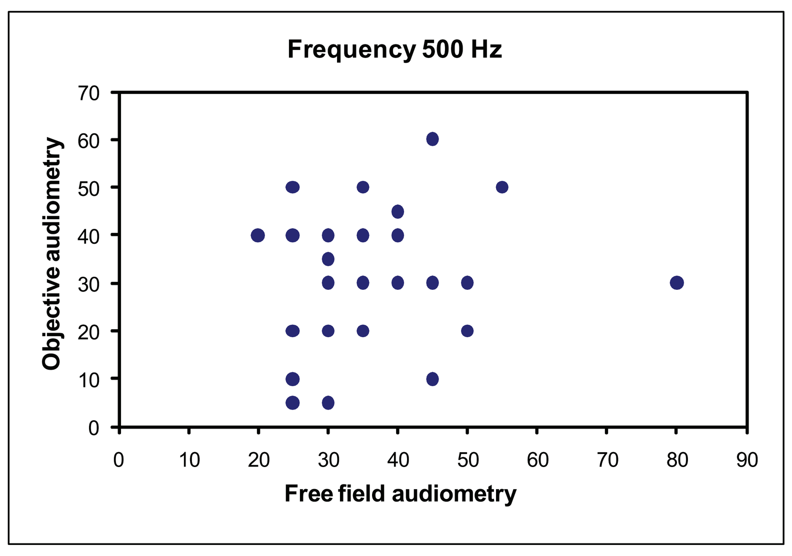


Table 2.

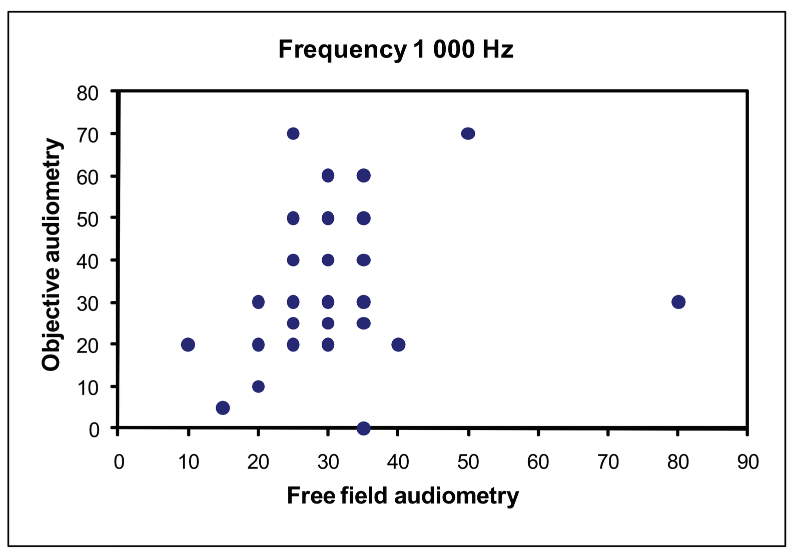


Table 3.

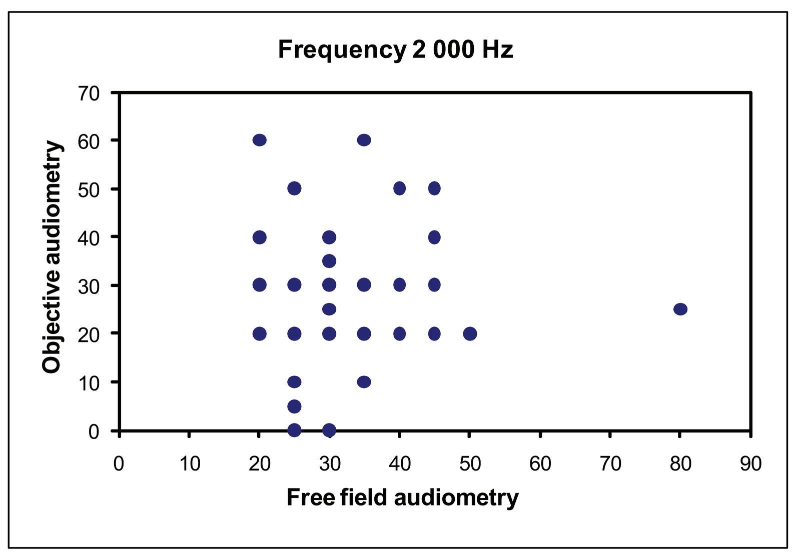


Table 3.

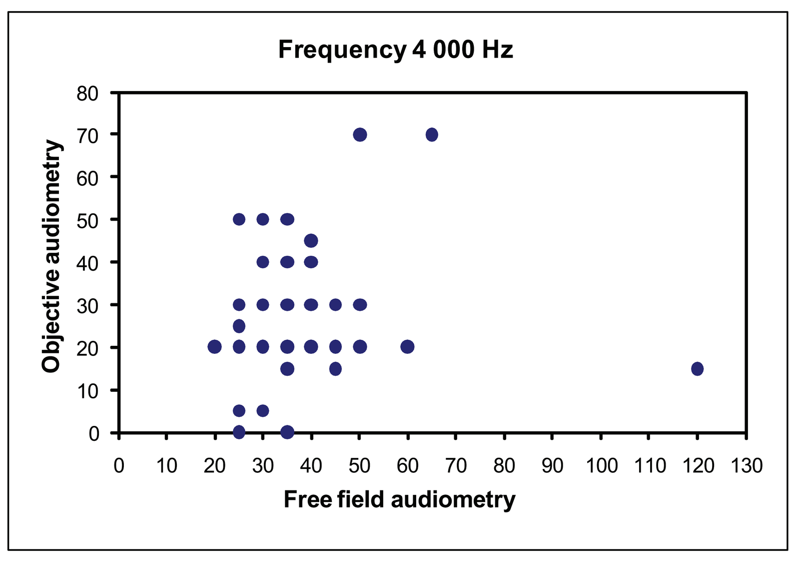


Table 4.

Discussion

Results of both measurements confirmed significant improvement of hearing in deaf patents with CI. The average threshold measured by objective method (ASSR) was nearly identical to the threshold measured by acoustic stimulation in free field condition. In two out of 4 frequencies (500 and 1000Hz) significant correlation has been confirmed or in other words significant difference between subjective and objective threshold has not been confirmed in implanted patients.

The major problem is technical realization of the testing. There are factors that may influence hearing thresholds measured by ASSR in implanted patients. Several papers show presence of artefacts in EEG in electrical stimulation. Artefacts may cause incorrect detection of responses. The most frequent way how to remove these artefacts is to use different filters (Parsa et al. 1998; Gnadt et al. 2003, Hofmann 2010, Menard 2004, Yang 2008).

Results of ASSR measurements in CI patients are stabile; in repeated measurements in the single subject the variations are minimal. Instable results were recorded in case when the electrodes were close to implant (ipsilateral). Yang (2008) also confirmed that more stabile results have been reached when electrodes were placed contralaterally. Less artefacts are present also in case when short duration stimuli are used (Menard 2004). Based on this information contralateral position of electrodes has been used in our setup.

Due to good correlation in our results we can assume that that ASSR response has been sufficiently filtered by the device with minimal artefacts. Recorded responses contain real electrophysiological response that can be used to define the hearing threshold in non-cooperating implanted patients. This precondition should be confirmed by additional measurements.

Conclusion

Measurement of ASSR is a suitable method to define the hearing threshold in patients with SNHL, in candidates for CI to define level of residual hearing as well as in patients after CI. One can assume that after confirmation of our preliminary results these methods will be used to measure frequency specific measurement of hearing threshold in 4 frequencies in non cooperating children after CI that enables more accurate fitting.

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