MULTI-FREQUENCY HEARING IMPROVEMENT ANALYSIS AS A METHOD EVALUATING RECOVERY IN PATIENTS WITH IDIOPATHIC SUDDEN SENSORINEURAL HEARING LOSS

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Abstract:

Introduction and objective

Hearing improvement assessment in patients with Idiopathic Sudden Sensorineural Hearing Loss (ISSNHL) is complex. Methods used to evaluate the effectiveness of ISSNHL therapy do not include variety of PTA (Pure Tone Audiometry) curves. The aim of this paper is to assess usefulness of Multi-Frequency Hearing Improvement Analysis (MHIA) as an alternative method employed to evaluate the effectiveness of the ISSNHL treatment.

Material and methods

Medical records of 218 patients with ISSNHL were statistically analysed in a retrospective study with regard to PTA results. Achieved results were compared using the following methods: Siegel's criteria, Wilson's criteria, and MHIA.

Results

The analysis based on Siegel's criteria, which concerned the effectiveness of therapy, was as follows: complete recovery: 94 (43,1%), partial recovery: 20 (9,2%), slight recovery: 17 (7,8%), no recovery: 87 (39,9%). The MHIA analysis revealed the following weighted arithmetic mean recovery rate: Air Conduction and Bone Conduction respectively – complete recovery (23,5%; 43,14%), partial recovery: (9,12%; 20,51%); slight recovery (6,65%; 7,4%), no recovery (68,36%; 54,98%).

Conclusions

MHIA corrects the overestimation of complete recovery rate based on Siegel's criteria. Using mean auditory threshold stimulus as a baseline to evaluate hearing improvement in studies could distort the interpretation of research findings. Clinical features and usability of MHIA in diverse groups of patients require further studies.

Keywords: sudden deafness, hyperbaric medicine, Siegel criteria, hearing assessment, steroid therapy.

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Introduction

Idiopathic Sudden Sensorineural Hearing Loss (ISSNHL) is defined as a sudden, subjective hearing loss in one or both ears. ISSNHL is diagnosed when vocal threshold stimulus is enlarged by not less than 30 dB in at least 3 frequencies [1] in Pure Tone Audiometry (PTA). PTA involves the use of the two following types of conductions: Bone Conduction (BC), and Air Conduction (AC). The most common methods used to estimate hearing improvement are Wilson's [2] and Siegel's [3] criteria. Wilson's criteria constitute a relative recovery assessment method. Some studies modify this method and describe a complete recovery as a 90% hearing recovery. Furthermore, they use reference values as a baseline [4]. This method defines recovery without considering hearing threshold quo-

tient prior/post therapy. Both methods evaluating the successfulness of therapy are mainly based on the measurement of the lowering of threshold auditory stimulus. Considering multiple voice frequencies analysed in PTA, PTA curves vary as follows: ascending, descending, flat, deep [5]. Current state of research does not clearly define recommendations concerning the ISSNHL treatment. There are studies proving that steroid therapy (ST) is beneficial [1-3, 6-8] and its therapeutic role is anti-inflammatory effect. The European Committee for Hyperbaric Medicine and the Polish Society of Audiology and Phoniatrics recommend the use of hyperbaric oxygen therapy (HBOT), whereas the Undersea and Hyperbaric Medical Society does not endorse this method [7-12]. Diverse pathophysiology of ISSNHL [13, 14] and various types of PTA curves require an individual approach to the treatment. Available research indicate that benefits may be found in certain types of PTA curves [15]. Moreover, they demonstrate that multi-frequency interpretation is an important step involved in supporting individual ISSNHL therapy. Individual therapy for various types of hearing impairments requires creating a more personal type of hearing improvement assessment method.

Aim of the study

The aim of this paper is to assess usefulness of Multi--Frequency Hearing Improvement Analysis (MHIA) as an alternative method used to evaluate the effectiveness of the ISSNHL treatment.

Material and methods

Medical records of 218 patients (117 males, 101 females, mean age 48,8 ±14,5 years old) admitted to Department of Hyperbaric Medicine of the Military Institute of Medicine – National Research Institute in Warsaw were subjected to retrospective analysis. Admissions of patients took place between 01.2018-12.2019. The authors state that this study was conducted in accordance with the Declaration of Helsinki: Recommendations guiding physicians in biomedical research involving human subjects. Journal of the American Medical Association, 277, 925-926. All the patients were treated with the use of BAROXHBO hyperbaric oxygen chamber, according to the following hyperbaric medicine procedure:

- compression to 2,5 ATA,
- total compression/decompression time: 10 minutes (1,5 meters/minute),
- oxygenation 3 x 20 minutes with 100% oxygen as breathing factor,
- oxygen breaks 2 x 5 minutes, performed routinely to prevent toxic influence to lungs and brain, were implemented,
- average duration of HBOT: 15,9 days (±4,1),
- average HBOT delay: 8,2 days (±6,6).

Steroid therapy (ST) parameters: initial average dosage of prednisone: 48,5 mg (±15,7), average duration of ST: 15,9 days (±7,8), average ST delay: 5,3 days (±5,7).

Exclusion criteria:

- age <18 years old,
- the start of HBOT 30 days after the onset of ISSNHL symptoms,
- coexisting cerebrospinal inflammation,
- neuropsychiatric disorder,
- vascular disorder,
- Meniere's disease,
- hereditary hearing disorder,
- inner ear malformations,
- facial nerve neuroma,
- bilateral ISSNHL,
- subsequent episode of ISSNHL.

Research participants were examined with the help of PTA before and after therapy. The therapy involved the use of Interacoustics AC40 audiometer in the following frequencies [Hz] (AC – 125, 250, 500, 1000, 1500, 2000, 3000, 4000, 6000, 8000; BC – 125, 250, 500, 1000, 1500, 2000, 3000, 4000). The gathered data were analysed using the following methods: Siegel's criteria, Wilson's criteria, and MHIA.

Wilson's criteria [2]

A complete recovery is defined as recovery of hearing to within 10 dB of the pre-hearing loss speech reception score or of the PTA score (if the loss was primarily in the high-frequency range). A partial recovery is defined as recovery of hearing to within 50% or more of the pre--hearing loss speech reception score or of PTA score (if the loss was in the high-frequency range). No recovery is defined as less than 50% hearing recovery[2].

Siegel's criteria [3]

Siegel's criteria as an absolute method used to evaluate hearing improvement are described as shown in the following table (Table 1).

Table 1. Siegel's criteria.

Recovery status	Auditory threshold stimulus after therapy (dB)	Lowering of the auditory threshold stimulus during therapy (dB)
Complete	<25	
Partial	25-44	>15
Slight	45-69	>15
No recovery	>70	<15

According to the current state of scientific data, Siegel's criteria were used to examine differences between mean values of auditory threshold stimulus before and after the therapy.

MHIA

MHIA is based on an absolute comparison method – Siegel's criteria. MHIA is a method used to analyse treatment results in the aforementioned group of patients. Examined frequencies are differentiated between AC and BC and they are taken into consideration individually regardless from a single patient score. Consecutive lower and higher frequencies are often in reference values in ascending and descending types of PTA curves. Thus,

in order to avoid overestimation of a complete recovery, PTA results are excluded when the auditory threshold stimulus is lower than 30 dB.

Statistical analysis

Statistical analysis has been performed with use of "Statistica 7.0" software. T-Student test has been performed in study group. Normal distribution has been confirmed by Kolmogorov-Smirnov test.

Results

Average pre-treatment and post-treatment threshold auditory stimuli displayed by 218 patients included in the study were respectively: 54,6 dB (±31,3), 39,6 dB (±32,2). Types of PTA curves were: ascending (24, 11%), descending (86, 39,9%), flat (63, 28,9%), deep (44, 20,2%). The average delay (in days) of implementing ST and HBOT was: 5,3 (±5,7), 12,1 (±6,7).

Wilson's criteria

Wilson's criteria were impossible to apply due to the following reason: pre-hearing loss PTA was not available for any patient and it would be strongly inaccurate to presume that all the patients had impeccable hearing before the onset of ISSNHL. Another key factor needed in order to apply Wilson's criteria was only useful in patients with primarily high-frequency hearing loss which constituted 87 patients (39,9%). This is not a representative group, hence it is not possible to extrapolate the results to the whole group of patients with ISSNHL.

Siegel's criteria

Regarding Siegel's criteria, the recovery rate was as follows (vide Table 2). Applying Siegel's criteria in this group revealed that there is a significant group (42 patients, 44,7% of complete recovery) that meets complete recovery criteria prior therapy.

Table 2. Siegel's criteria in comparison to the other studies.

	Our study	Xie et al. [17]	Sung et al. [23]	Günel et al. [24]2
Complete recovery	43,1%	19,7%	50,9%	11,1%
Partial recovery	9,2%	17,4%	9,8%	22,2%
Slight recovery	7,8%	13,5%	5,9%	40,7%
No recovery	39,9%	49,4%	25,5%	25,9%

MHIA results

(Table 3, 4) Regarding mean PTA results as well as AC and BC, in spectrum of all frequencies, lowering of the auditory threshold stimulus was detected. Especially visible differences were observed at frequencies 500-2000 Hz. Slight recovery of hearing was visible at higher frequencies (4000-8000 Hz).

Table 3. Mean values of AC before and after therapy.

Frequency (Hz)	AC					
	before (dB)	after (dB)	variation (dB)	variation (%)	T	p
125	49,6	35,9	13,8	27,8%	4,012	0,000
250	51,4	36,1	15,3	29,8%	4,85	0,000
500	55,9	37,6	18,3	32,7%	5,626	0,000
1000	55,4	38,7	16,7	30,2%	5,010	0,000
1500	68,2	40,0	28,2	41,4%	5,790	0,000
2000	55,7	41,4	14,4	25,8%	4,934	0,000
3000	60,7	46,9	13,8	22,7%	3,949	0,000
4000	61,4	49,3	12,1	19,7%	3,673	0,000
6000	67,1	55,3	11,8	17,6%	3,428	0,001
8000	64,9	57,9	7,0	10,8%	2,063	0,040

Table 4. Mean values of BC before and after therapy.

Frequency (Hz)	BC					
	before (dB)	after (dB)	variation (dB)	variation (%)	t	p
250	42,1	26,5	15,6	37,1%	4,142	0,000
500	49,1	29,2	19,9	40,5%	5,592	0,000
1000	50,1	31,1	19,0	38,0%	5,133	0,000
1500	71,1	33,3	37,8	53,1%	6,647	0,000
2000	53,3	35,5	17,7	33,3%	4,768	0,000
3000	57,8	38,6	19,2	33,2%	4,577	0,000
4000	54,7	39,1	15,5	28,4%	4,173	0,000

Having disqualified initially correct scores (<30 dB), MHIA was used to analyse the remaining data concerning certain frequencies (Table 5, 6). The therapy had a different impact on various frequencies. The highest rate of complete recovery was detected at 4000 Hz in BC. The smallest influence of therapy was detected at 8000 Hz, AC. Recovery in BC was more visible than in AC.

Table 5. Recovery proportions in AC.

Frequency(Hz)	Recovery proportions								
	Incorrect results count (n)	Complete recovery		Partial recovery		Slight recovery		No recovery	
		(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
125	94	16	17,0%	15	16,0%	6	6,4%	57	60,6%
250	135	39	28,9%	14	10,4%	8	5,9%	74	54,8%
500	152	50	32,9%	17	11,2%	14	9,2%	71	46,7%
1000	147	44	29,9%	4	2,7%	5	3,4%	94	63,9%
1500	64	15	23,4%	5	7,8%	3	4,7%	41	64,1%
2000	148	31	20,9%	3	2,0%	12	8,1%	102	68,9%
3000	126	23	18,3%	8	6,3%	10	7,9%	85	67,5%
4000	166	25	15,1%	13	7,8%	7	4,2%	121	72,9%
6000	146	19	13,0%	8	5,5%	9	6,2%	110	75,3%
8000	178	20	11,2%	6	3,4%	3	1,7%	149	83,7%
weighted arithmetic mean			23,5%		9,12%		6,65%		68,36%

Table 6. Recovery proportions in BC.

Frequency(Hz)	Recovery proportions								
	Incorrect results count (n)	Complete recovery		Partial recovery		Slight recovery		No recovery	
		(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
250	108	41	38,0%	7	17,1%	0	0,0%	60	55,6%
500	128	47	36,7%	9	19,1%	12	9,4%	60	46,9%
1000	126	38	30,2%	10	26,3%	6	4,8%	72	57,1%
1500	57	13	22,8%	3	23,1%	4	7,0%	37	64,9%
2000	135	39	28,9%	7	17,9%	12	8,9%	77	57,0%
3000	114	26	22,8%	8	30,8%	5	4,4%	75	65,8%
4000	144	97	67,4%	7	7,2%	9	6,3%	31	21,5%
weighted arithmetic mean			43,14%		20,51%		7,4%		54,98%

Discussion

Diverse morphology of PTA curves naturally involves problems with assessing hearing improvement especially in numerous groups of patients. Amelioration and unification of assessment methods examining the effectiveness of treatment is crucial to compare therapy results between various studies.

It was impossible to apply Wilson's criteria [2], due to primarily erroneous assumptions. Pre-hearing loss speech reception score also could not be considered, because some patients demonstrate their previous PTA results but they were not up-to-date. Therefore, they should not be treated as a baseline to assess ISSNHL recovery. Another key factor needed to apply Wilson's criteria is hearing impairment present at high frequencies. Such an impairment was present only in patients with descending PTA curves (39,9%). Some studies modify Wilson's criteria and they treat reference values as a baseline to estimate hearing recovery rate [4]. This method can be used only in patients without previous hearing impairments. Nevertheless, it is difficult to prove that a patient had not suffered from any hearing impairment. There are some potential solutions to estimate pre-hearing speech reception score loss, such as comparing PTA curve with an unaffected ear [16].

In this study, Siegel's criteria [3, 17, 18] revealed an overestimation of a complete recovery. This overestimation and an irregular impact on final hearing improvement require multi-frequency approach to assess the effectiveness of the ISSNHL therapy. Average auditory threshold stimulus can reveal a complete recovery and, simultaneously, meet the criteria of ISSNHL in PTA. This limitation has resulted from ascending and descending PTA curves. Recovery rate with comparison to other studies applying Siegel's criteria is presented in table 2. As shown in the table, differences between the results of the studies are significant. Varying outcomes of the implemented therapy might be caused by differences existing in study groups, PTA curves, therapy protocols. Multi-frequency analysis is a possible solution to improve prognosis of recovery by not treating differences of PTA curves as an interfering factor. Several studies modify Siegel's criteria in order to assess hearing improvement. Published studies tried to assess recovery with regard to before-therapy hearing impairment level[19]. This solution allows to assess successfulness of therapy while considering the ISSNHL level. It can also be used as a method to predict treatment effectiveness before implementing therapy.

The current state of scientific data presents absolute methods which have limitations comparable to those presented in Siegel's criteria. A method presented by a Korean study [20] simplifies Siegel's criteria estimating the final hearing level as better than 25 dB. Moreover, it reduces hearing gain by at least 15 dB compared to pre-treatment level. This study algorithm included examination only of four frequencies (0,5 kHz, 1 kHz, 2 kHz, 4 kHz). A small number of analysed frequencies can potentially improve Siegel's overestimation. Employed reductions allow to compare the results between studies applying Siegel's criteria with taking into account only 4 examined frequencies. Unfortunately, there is still a number of analysed frequencies which does not include any deafness on boundary frequencies (125, 250, 6000, 8000). These frequencies have usually enlarged auditory threshold stimuli in ascending and descending PTA curves which constituted 111 (50,9%) types included in our study. It makes it a relatively large group. Excluding patients with boundary types of ISSNHL has a potential impact on final treatment results [18, 21, 22]. Our study revealed that the implemented therapy had a complex effect on the results of therapy. The numbers of complete recovery differ from one another at various frequencies (AC: 8000 Hz: 11,2% vs 500 Hz: 32,9%; BC: 1500 Hz: 22,8% vs: 4000Hz: 67,4%). In order to assess how the therapy may influence final treatment results, a further study is required. Moreover, it is essential to stress the fact that the impact of therapy is nonlinear. Multi-frequency approach to assess the effectiveness of implemented therapy analysis can potentially be a step into individualizing ISSNHL therapy. According to the current state of scientific data, there is evidence proving that the implemented therapy may have a different influence on auditory threshold stimulus, which is important for certain frequencies. An American study [15] proved a selective therapeutical activity of nortriptyline and topiramate detectable at hearing impairment at lower frequencies. In comparison to our study and with regard to the fact that ascending types of PTA curves constituted 11% of study group, the influence of mentioned therapy on the rest of the group can make this relation potentially insignificant. Supporting the multivariate ISSNHL treatment analysis used in the study [17] together with MHIA makes it possible to create guidelines for a particular therapy with regard to PTA types, what consequently can improve total outcomes of the ISSNHL therapy. Depending on the examined frequency, recovery rates presented in table 6. differs from each other by up to 44,6% (complete recovery 4000 Hz vs 3000 Hz). It shows that the influence which the therapy has on final hearing improvement in patients with ISSNHL is complex.

Conclusions

MHIA corrects overestimation of complete recovery rate based on Siegel's criteria. Due to the diversity of the PTA curves and rated multiplicity of frequencies, the effectiveness of the ISSNHL therapy assessment is complex. Using mean auditory threshold stimulus as a baseline to evaluate hearing improvement in studies could distort the interpretation of research findings. Clinical features and usability of MHIA in diverse groups of patients require further studies.

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