EVALUATION AND INTERPRETATION OF PRELIMINARY RESULTS OF AUDIOMETRIC TESTS IN SUBJECTS WITH IMPAIRED HEARING EXPOSED TO CONDITIONS OF HYPERBARIC OXYGEN THERAPY

Zdenka KRAJČOVIČOVÁ[1]* – Rastislav ZIGO[2] – Iveta MATIŠÁKOVÁ[1] – Vladimír MELUŠ[1] – Katarína GERLICHOVÁ[1]

[1]*Faculty of Healthcare, Alexander Dubček University of Trenčín, Študentská 2, 911 50 Trenčín, Slovak Republic*
[2]*Faculty Hospital Trenčín, ENT Clinic, Legionárska 28, 91171 Trenčín, Slovak Republic*
*Corresponding author E-mail address: zdenka.krajcovicova@tnuni.sk

Abstract
Hearing loss is a serious interference with the individual's quality of life. Among the new options of its therapy belongs Hyperbaric Oxygen Therapy (HBOT). In our preliminary study, we evaluated the results of audiometric tests of the first 9 probants exposed to HBOT and 8 individuals of control group treated without HBOT support, all with sudden idiopathic hearing loss. Obtained results showed remarkable positive influence of HBOT on the level of improvement and compensation of hearing impairment in tested probants in comparison with control group. Although the present number of tested individuals does not allow us to postulate a definitive conclusion, we found notable HBOT positive impact on the average rate of improvement of hearing individuals.

Key words: Hearing loss, Hyperbaric Oxygen Therapy, Audiometric test

Introduction

Hearing impairment affects the majority of older adults, however, sudden hearing loss are common even in people at a younger age as a result of injury, disease or exposure to excessive acoustic load. Hearing difficulties hamper communication with people and may make it hard to participate in activities that require following speech [1]. This has led to an important humanitarian cost in terms of isolation, frustration, depression, cognitive decline and decrease in quality of life, along with an enormous and growing economic burden in health care costs [2-6]. Persons with hearing difficulty may begin to avoid other people, withdraw from various activities, as has been indicated by cross-sectional studies, and spend more time at home [1]. Previous longitudinal studies have shown that being homebound may negatively affect mental health [7] and physical functioning [7-9].

Sudden sensorineural hearing loss (SSNHL) is thought to be the clinical manifestation of various pathologic conditions, and is not a simple disease entity [10]. It is defined as 30dB or more of sensorineural hearing loss over at least three consecutive frequencies within 3 days [11-16]. In total, 85–90% of cases are idiopathic at presentation [17]. Viral infections, vascular compromise, autoimmunity, and intralabyrinthine membrane rupture are considered as the main potential causes of idiopathic SSNHL (ISSNHL) [11, 18-20]. The degree of hearing loss, time period from the onset of hearing loss and beginning of treatment, audiometric configuration, comorbidities (hypertension, diabetes), and presence of vestibular symptoms and tinnitus may influence the course of ISSNHL [18, 21].

Because of the multifactorial etiopathology of ISSNHL, many different regimens have been applied for the treatment of this disease, including vasodilators, anticoagulants, corticosteroids, vitamins, plasma expanders, histamine, antiviral agents, batroxobin, amidotrizoate, magnesium, stellate ganglion block, or carbogen [10]. The aim of our study was to show the possibility of SSNHL therapy through hyperbaric oxygen therapy.

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy is a therapeutic approach where the patient is exposed to 100% oxygen at pressures higher than ambient (1 ATA). This leads to an increased blood oxygen level, which than can penetrate to ischemic areas more deeply than under normobaric conditions [22, 23]. Normally 97% of the oxygen transported from the lungs to the tissues is carried in chemical combination with hemoglobin or red blood cells, and the remaining 3% in a dissolved state in plasma. Under hyperbaric conditions, it is possible to dissolve sufficient oxygen, i.e., 6 vol% in plasma, to meet the usual requirements of the body. In this case oxyhemoglobin will pass unchanged from the arterial to the venous side because the oxygen physically dissolved in solution will be utilized more readily than that bound to hemoglobin [24, 25]. When hyperbaric oxygen therapy results in venous blood being 100% saturated with oxygen, there is a rise in blood pCO_2 and a shift of pH to the acid side. This is due to loss of hemoglobin available to transport CO_2. This affects only the 20% of the venous content of CO_2 which is transported by hemoglobin. Excess CO_2 is transported by the H_2CO_3/HCO_3 mechanism, as well as by entering into physical solution in plasma [24, 25].

The equipment required consists of a pressure chamber, which may be of rigid or flexible construction, and a means of delivering 100% oxygen. Operation is performed to a predetermined schedule by trained personnel who monitor the patient and may adjust the schedule as required (Fig.1).

Figure 1 *Hyperbaric chamber of Centre for hyperbaric oxygen therapy of Faculty of Healthcare of Alexander Dubček university of Trenčín*

Aim of study

With the aid of appropriate statistical methods we processed the first data obtained in subjects exposed to HBOT and assess its impact on the rate of recovery.

Material and methods

We evaluated data of audiometric tests of 9 probants exposed to HBOT together with 8 individuals without HBOT (control group), all with sudden hearing loss. The examinations were performed at frequencies 250 dB, 500 dB, 1000 dB, 2000 dB, 4000 dB, 6000 dB and 8000 dB.

Both groups have been statistically characterized by number (n), arithmetical mean ($\bar{x}$), standard deviation (sd), median (x_m), minimal ($min.$) and maximal value ($max.$). For paired variables we used non parametrical Wilcoxon test. Testing of independent variables was performed with the Mann-Whitney test. Differences between groups were considered to be statistically significant when probability level of test result was $p<0.05$.

Results and discussion

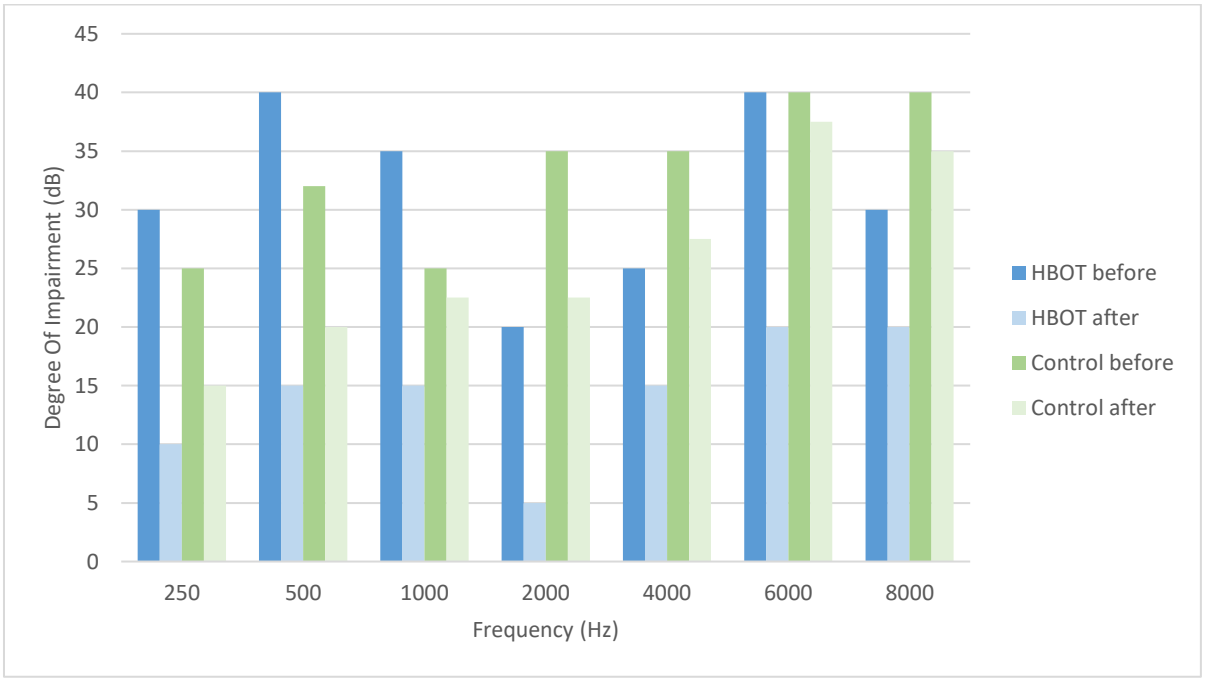
Results of our pilot study are shown in Table 1. The results show that, in the case of using the exposure HBOT, the differences between the values of the pre-treatment and post-treatment much more pronounced. This character of data can be observed continuously on the results of all seven acoustic frequencies. Despite the small number of samples in patients treated with HBOT are differences before vs. after therapy statistically significant at frequencies 1000 dB ($p=0.02$), 2000 dB ($p=0.03$) and 8000 dB ($p=0.03$). The results of the control group did not reached such values (Graph 1). In the case of the frequency of 4000 Hz, the results of probants were statistically significantly better in comparison with controls (Mann-Whitney test, $p<0.05$; HBOT group x_m =15, n=9, Control group x_m =27.5, n=8).

For other frequencies, comparison of treated and control groups were not statistically significant (Mann-Whitney test, $p>0.05$, particular results not listed). We are aware of the limited number of processed data from tested subjects. Nevertheless, it would not be sufficient to interpret the observed results only under the simplified approach with conclusion of lower values of arithmetic mean and median in probants with HBOT. On the other hand, we do not overestimate possibilities of used statistical tests. With considerable caution, however, we can conclude that there is a trend of better average progress in therapy supported with HBOT, which is given by percentage improvement in particular acoustic frequencies.

Table 1 *Statistical parameters of both groups of treated patients*

Freq. (dB)	Group	Examined	*n*	$\bar{x}$	*sd*	x_m	*min.*	*max.*	*p*
250	HBOT	Before	9	27.7	15.8	30	5	45	0.07
		After	9	16.7	15.0	10	0	40	
	Control	Before	8	32.5	28.7	25	0	75	0.44
		After	8	20.6	14.5	15	5	45	
500	HBOT	Before	9	32.2	18.6	40	5	50	0.05
		After	9	20.0	15.6	15	5	45	
	Control	Before	8	36.9	32.6	32	5	85	0.31
		After	8	24.4	14.5	20	10	50	
1000	HBOT	Before	9	30.6	19.1	35	10	65	0.02
		After	9	17.8	17.2	15	0	45	
	Control	Before	8	35.0	31.8	25	0	85	0.22
		After	8	26.3	16.6	22.5	5	55	
2000	HBOT	Before	9	27.2	18.4	20	10	60	0.03
		After	9	17.2	21.1	5	0	55	
	Control	Before	8	36.9	30.1	35	0	80	0.19
		After	8	25.6	16.6	22.5	0	55	
4000	HBOT	Before	9	27.2	17.7	25	0	50	0.05
		After *	9	16.1	17.6	15	0	60	
	Control	Before	8	42.5	26.6	35	10	80	0.19
		After *	8	36.3	23.1	27.5	15	80	
6000	HBOT	Before	9	32.7	18.7	40	5	60	0.08
		After	9	23.3	18.2	20	5	65	
	Control	Before	8	41.9	21.5	40	10	70	0.13
		After	8	36.3	18.5	37.5	10	60	
8000	HBOT	Before	9	31.7	18.0	30	5	60	0.03
		After	9	23.3	17.5	20	5	65	
	Control	Before	7	35.7	18.8	40	10	65	0.25
		After	7	33.6	18.0	35	10	60	

Legend: *n* – number of patients, $\bar{x}$ – arithmetical mean, *sd* – standard deviation, x_m – median, *min*. – minimal value, *max*. – maximal value, p – probability value of Wilcoxon test, * statistically significant difference of HBOT group compared to controls ($p<0.05$; Mann-Whitney test), Before – probants examined before treatment, After – probants examined after treatment



Graph 1 *Rate of change of the hearing impaired in individual frequencies*

Conclusion

Hearing difficulties are prevalent not only among older people and can lead to difficulties in social interaction. HBOT is the unique method of increasing concentration of oxygen in the inner ear fluids thus facilitates the regeneration process. In combination with therapeutic targeting of excessive free radical formation and cochlear blood flow regulation may be therefore a useful strategy to improving auditory function of selected hearing diseases and disorders.

Our preliminary results indicated, that HBOT has for the treatment of sudden hearing disorders important influence. Its disadvantage lies in the vast material and technical demands. As a result, it is limited to a small number of workplaces, and there are not existing uniform valid and obligatory guidelines. Further comprehensive clinical trials are needed in formation of standardized therapeutical procedures with defined sequences of treatment interventions and known estimated range of laboratory determinated parameters. The task of our project is to fill-out this area of knowledge with the emphasis on the needs of the local population.

Acknowledgements

This publication was created in the frame of the project "Completion of the technical infrastructure for the development of science and research at Alexander Dubček University of Trenčín through Hyperbaric Oxygen Therapy", ITMS code 26210120019, based on the Operational Programme Research and Development and funded from the European Social Fund.

References

[1] Mikkola TM, Polku H, Portegijs E, Rantakokko M, Tsai LT, Rantanen T, Viljanen A. Self-reported hearing is associated with time spent out-of-home and withdrawal from leisure activities in older community-dwelling adults. Aging Clin Exp Res. 2015 Jun 11. [Epub ahead of print].

[2] World Health Organization. Active Ageing, A Policy Framework. 2002; Available online at: http://whqlibdoc.who.int/hq/2002/who_nmh_nph_02.8.pdf

[3] World Health Organization. Deafness and hearing loss, Fact sheet N°300. 2013; Available online at: http://www.who.int/mediacentre/factsheets/fs300/en/index.html

[4] Huang Q, Tang J. Age-related hearing loss or presbyacusis. Eur Arch Otorhinolaryngol 2010; 267: 1179–1191.

[5] Kidd III AR, Bao J. Recent advances in the study of age-related hearing loss: a mini-review. Gerontology 2012; 58: 490–496.

[6] Ciorba A, Bianchini C, Pelucchi S, Pastore A. The impact of hearing loss on the quality of life of elderly adults. Clin Interv Aging 2012; 7: 159–163.

[7] Cohen-Mansfield J, Shmotkin D, Hazan H The effect of homebound status on older persons. J Am Geriatr Soc 2010; 58: 2358–2362.

[8] Jacobs JM, Cohen A, Hammerman-Rozenberg R et al. Going outdoors daily predicts long-term functional and health benefits among ambulatory older people. J Aging Health 2008; 20: 259–272.

[9] Fujita K, Fujiwara Y, Chaves PH et al. Frequency of going outdoors as a good predictors for incident disability of physical function as well as disability recovery in community-dwelling older adults in rural Japan. J Epidemiol 2006; 16: 261–270.

[10] Suzuki H, Koizumi H, Ohkubo JI, Hohchi N, Ikezaki S, Kitamura T. Hearing outcome does not depend on the interval of intratympanic steroid administration in idiopathic sudden sensorineural hearing loss. Eur Arch Otorhinolaryngol. 2016 Feb 15. [Epub ahead of print].

[11] Psifidis AD, Psillas GK, Daniilidis JCh. Sudden sensorineural hearing loss: long-term follow-up results. Otolaryngol Head Neck Surg 2006; 134: 809-815.

[12] Chao TK, Chen TH. Distortion product otoacoustic emissions as a prognostic factor for idiopathic sudden sensorineural hearing loss. Audiol Neurootol 2006; 11: 331-338.

[13] Penido Nde O, Ramos HV, Barros FA, Cruz OL, Toledo RN. Clinical, etiological and progression factors of hearing in sudden deafness. Braz J Otorhinolaryngol 2005; 71: 633-638.

[14] Sano H, Okamoto M, Ohhashi K, Iwasaki S, Ogawa K. Quality of life reported by patients with idiopathic sudden sensorineural hearing loss. Otol Neurotol 2013; 34: 36-40.

[15] Borton SA, Mauze E, Lieu JE. Quality of life in children with unilateral hearing loss: a pilot study. Am J Audiol 2010; 19: 61-72.

[16] Krajčovičová Z, Zigo R, Meluš V. Possibilities of hyperbaric oxygen therapy usage in comprehensive treatment of selected hearing diseases and disorders. University review 2015; 9 (2-3): 45-53.

[17] Rauch SD. Clinical practice. Idiopathic sudden sensorineural hearing loss. N Engl J Med 2008; 359: 833-840.

[18] Enache R, Sarafoleanu C. Prognostic factors in sudden hearing loss. J Med Life 2008; 1: 343-347.

[19] Eisenman D, Arts HA. Effectiveness of treatment for sudden sensorineural hearing loss. Arch Otolaryngol Head Neck Surg 2000; 126: 1161-1164.

[20] Kaya H, Koç AK, Sayın İ, Güneş S, Altıntaş A, Yeğin Y, et al. Vitamins A, C, and E and selenium in the treatment of idiopathic sudden sensorineural hearing loss. Eur Arch Otorhinolaryngol 2015; 272: 1119-1125.
[21] Edizer DT, Çelebi Ö, Hamit B, Baki A, Yiğit Ö. Recovery of Idiopathic Sudden Sensorineural Hearing Loss. J Int Adv Otol 2015; 11 (2): 122-126.
[22] Parabucki AB, Bozić ID, Bjelobaba IM, Lavrnja IC, Brkić PD, Jovanović TS, Savić DZ, Stojiljković MB, Peković SM. Hyperbaric oxygenation alters temporal expression pattern of superoxide dismutase 2 after cortical stab injury in rats. Croat Med J 2012; 53 (6): 586-597.
[23] Baňárová P, Malay M, Kotyra J, Černický M. Potenciál využitia hyperbarickej oxygenoterapie pri funkčných poruchách pohybového systému. Zdravotnícke listy 2014; 2 (3): 23-27.
[24] Jain KK. Textbook of hyperbaric medicine. Hogrefe and Huber Publishers 2009, 578 pp.
[25] Krajčovičová Z, Meluš V. Proposed mechanisms of action of selected antioxidant defences inducted by hyperbaric oxygen therapy. University review 2014; 8 (1-2): 2-8.