



## Treatment of sudden sensorineural hearing loss with hyperbaric oxygenation – our experience

Lečenje iznenadne senzorične naglušnosti hiperbaričnom oksigenacijom – naša iskustva

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### Abstract

**Background/Aim.** Sudden sensorineural hearing loss is manifested by the loss of hearing for more than 30 dB at three consecutive frequencies in the timeframe of 72 h. It is of unclear etiology and pathogenesis, which leads to the use of different therapeutic methods. Treatment protocols are not compliant, making it difficult to objectively quantify their impact. The aim of this study was to show the effect of hyperbaric oxygen therapy as the only method for the treatment of sudden sensorineural hearing loss. **Methods.** This retrospective study included 20 patients treated for sudden sensorineural hearing loss with hyperbaric oxygenation (HBO) in the period from 2004 to 2014. The study was conducted in the specialized medical clinic for hyperbaric and underwater medicine, HBO Medical Center in Belgrade. The patients were treated according to the following protocol: a session of 60 min at the pressure of 2 bars (2ATA) two times a day, a total of 30 sessions. Assessment of the therapy effects was performed by observing the change in

the hearing threshold at the frequencies of 500, 1,000, 2,000 and 4,000 Hz at the end of the treatment. **Results.** After the completion of treatment according to the protocol, a full hearing recovery (total improvement of hearing damage or achieving final hearing threshold above 25 dB) was found in 11 (55%) of the patients. A partial recovery (hearing improvement of up to 15 dB, and a final hearing threshold below 45 dB) occurred in 4 (20%) of the patients. In 5 (25%) of the patients, improvement was not verified (there was no recovery or it was less than 5 dB). The average absolute hearing recovery was 24.94 dB. The mean relative hearing recovery was 65.45%. **Conclusion.** Because of the unclear multifactorial etiopathogenesis of this disease, there are many therapeutic protocols. Based on the results of our study HBO therapy could be recommended primarily as the treatment for sudden sensorineural hearing loss.

**Key words:** hearing loss, sudden; hearing tests; hyperbaric oxygenation; recovery of function.

### Apstrakt

**Uvod/Cilj.** Iznenađna senzorične naglušnosti manifestuje se gubitkom sluha za više od 30 dB na tri uzastopne frekvencije tokom 72 časa. Nejasne je etiologije i patogeneze, što je dovelo do upotrebe različitih terapijskih sredstava. Protokoli lečenja nisu usaglašeni, što otežava objektivnu kvantifikaciju njihovog učinka. Cilj rada bio je da se prikaže efekat terapije hiperbaričnom oksigenacijom (HBO) kao jedine metode u lečenju iznenadne senzorične naglušnosti. **Metode.** Ova retrospektivna studija obuhvatila je 20 bolesnika lečenih od iznenadne senzorične naglušnosti primenom hiperbarične oksigenacije u periodu od

2004. do 2014. godine u specijalističkoj lekarskoj ordinaciji za hiperbaričnu i podvodnu medicinu (HBO Medicinski centar u Beogradu). Lečenje je sprovedeno prema protokolu, 2 × dnevno po 60 min na pritisku od 2 bara (2 ATA), ukupno po 30 seansi. Procena dejstva primenjene terapije vršena je posmatranjem promene praga sluha na frekvencijama 500, 1 000, 2 000 i 4 000 Hz posle sprovedene kompletne terapije. **Rezultati.** Posle sprovedenog lečenja prema protokolu, potpuni oporavak sluha (postignuto potpuno poboljšanje oštećenja sluha, odnosno konačni prag sluha iznad 25 dB) zabeležen je kod 11 (55%) bolesnika. Delimičan oporavak (poboljšanje sluha do 15 dB, odnosno konačni prag sluha ispod 45 dB) zabeležen je kod 4 (20%)

bolesnika. Kod 5 (25%) bolesnika nije potvrđeno poboljšanje (nije došlo do oporavka ili je ono bilo manje od 5 dB). Prosečan apsolutni oporavak sluha iznosio je 24,94 dB. Prosečni relativni oporavak sluha iznosio je 65,45%. **Zaključak.** Zbog nejasne multifaktorijalne etiopatogeneze ovog oboljenja postoji mnogo terapijskih protokola. Na osnovu rezultata našeg istraživanja može se preporučiti pri-

marno lečenje iznenadne senzorneuralne nagluposti hiperbaričnom oksigenacijom.

**Ključne reči:**  
gluvoća, iznenadna; sluh, ispitivanje; hiperbarična oksigenacija; funkcija, povratak.

## Introduction

Sudden sensorineural hearing loss (SSHL) is the sudden total or partial hearing loss of sensorineural type, often without clear cause. The literature describes it under various names: acute hearing loss, acute sensorineural hearing loss, and acute cochlear deafness. The disease was described for the first time by De Kleyn about 60 years ago. It occurs spontaneously within a few seconds, minutes or hours, it is mostly one-sided. The average hearing loss is between 50 and 70 dB. The American Society of Otorhinolaryngologists (American Academy of Otorhinolaryngology) defines the sudden hearing loss as a kind of sensorineural hearing loss with a reduction in hearing threshold of at least 30 dB at three consecutive frequencies, over a period of 72 hours<sup>1</sup>. It is characterized by buzzing, and sometimes dizziness of varying intensity<sup>2</sup>. It is rarely seen in children and usually affects the population aged 20 to 60 years of age and it is equally represented among the sexes<sup>3</sup>. It can occur in people with previously normal hearing or as an acute deficit of the previously damaged hearing. It is usually unilateral, but it occurs in both sides with the same frequency. In about 2% of the cases it affects both sides at the same time<sup>4</sup>. The incidence is 5 to 20 patients per 100,000 population per year<sup>5</sup>. The etiology most often cannot be established. In the literature, there are more than 100 causal agents for the disease quoted<sup>5</sup> and the most frequently referred are viral infections, circulatory disorder, trauma, autoimmune disease of the inner ear. However, the most common form is the idiopathic sudden sensorineural hearing loss and it is present in about 80%, and according to some authors up to 90% of the cases of sudden hearing loss<sup>6</sup>. According to the latest theories on the etiology of sudden sensorineural hearing loss, the following factors are of importance: the anatomy of the blood vessels of the inner ear, physiology of microcirculation of blood and inner ear, cell metabolism of Corty's organ<sup>7</sup>. Because of multiple etiological explanations for the genesis of the disease in the last 50 years, 50 different treatment protocols have been developed<sup>5</sup>. They range from the use of vasoactive drugs, corticosteroids, hyperbaric oxygenation (HBO), vitamin E, sedatives, calcium antagonists, prostaglandins, carbogen, magnesium, preparation of Ginkgo biloba extract, to surgical procedures. The greatest significance for a favorable outcome of the treatment has immediate implementation of therapy and the implementation of the entire treatment protocol. After the application of adequate therapy a good recovery is often achieved, although some patients have spontaneous and complete recovery of hearing without any treatment. Relapses are also possible<sup>8</sup>.

Hyperbaric medicine is a clinical discipline where the main therapeutic substrate is 100% oxygen (O<sub>2</sub>) that is inhaled under conditions of high pressure, above 1 bar (101 kPa, 760 mmHg), also known as hyperbaric oxygen, and is applied in special devices, hyperbaric chambers<sup>9</sup>. HBO therapy as a therapeutic method has been used for the treatment of various diseases in the field of human medicine, and for the treatment of sudden hearing loss as well.

HBO increases the amount of oxygen in the tissues at the expense of physically dissolved oxygen in the blood plasma and thus alleviates or completely eliminates the hypoxia. It also improves blood circulation by reducing plasma viscosity, reducing platelet aggregation, accelerating neocapillarization, the creation of new blood vessels and increasing the flexibility of red blood cells<sup>9</sup>.

The aim of this study was to investigate the effect of HBO therapy as the single method for the treatment of sudden sensorineural hearing loss.

## Methods

This retrospective study included 20 patients with unilateral sudden sensorineural hearing loss, treated with hyperbaric oxygen in the period from 2004 to 2014 in a specialized medical clinic for hyperbaric and underwater medicine, HBO Medical Center in Belgrade. The symptoms occurred for the first time in all of the subjects, what was verified by medical history of each patient.

The diagnosis of sudden sensorineural hearing loss in all the patients was made based on anamnesis, otorhinolaryngology examination, audiometry, impedancemetry and in case of present dizziness, vestibular testing was done. The existence of previous hearing loss, tinnitus and vertigo were determined by anamnestic data. In all the patients unilateral sensorineural hearing loss of varying degrees was confirmed on the basis of pure tone audiometry.

The study included only patients with sudden hearing loss, with hearing decrease of more than 30 dB at three consecutive frequencies in the range between 500 Hz and 4000 Hz in 72 h. The patients were divided according to gender, age, the presence of other symptoms (tinnitus, vertigo) and shape of audiometric curve.

On the basis of hearing loss (average hearing loss at frequencies 500, 1,000, 2,000 and 4,000 Hz), all the subjects were divided into 4 groups. The first group consisted of subjects with mild hearing loss (40 dB), the other with moderate hearing loss (41 dB to 60 dB), the third with a severe hearing loss (61 dB to 80 dB), and the fourth group of patients with deafness (over 80 dB).

The treatment was done according to the following protocol: a session of 60 min at the pressure of 2 bars (2ATA) twice a day, in total 30 sessions over 15 days. The result of treatment was assessed on the basis of changes in the average hearing threshold at frequencies 500, 1,000, 2,000 and 4,000 Hz after the end of treatment. Based on the results obtained, the treated patients were divided into 3 groups. The group I included patients with no recovery recorded, or it was less than 5 dB. The group II included patients with recorded hearing improvement to 15 dB and whose final hearing threshold was below 45 dB. In the group III there were patients who achieved complete improvement of the quality of hearing, or those with the final hearing threshold above 25 dB. Hearing threshold of the affected ear before the treatment was marked as the initial hearing threshold (IHT). ITH is equal to the average hearing threshold at 500, 1,000, 2,000 and 4,000 Hz of the affected ear. In the same way the final hearing threshold (FHT) was determined, which was equal to the average hearing threshold at 500, 1,000, 2,000 and 4,000 Hz of the affected ear at the end of the therapy. Improvement of hearing we defined as absolute and relative. Absolute hearing improvement (AHI) was the difference in decibels between the initial and final hearing threshold ( $AHI = IHT - FHT$ ). Relative hearing improvement (RHI) was the quotient of absolute hearing improvement, and the differences between the initial hearing threshold of the affected ear and the average hearing threshold (AHT) of the second a healthy ear, multiplied with 100 ( $RHI = AHI / IHT - AHT \times 100$ ). (AHT = average hearing thresholds at 500, 1,000, 2,000, 4,000 Hz).

## Results

The study included 13 (65%) men and 7 (35%) women. There was no statistically significant difference in the distribution of sexes ( $= 1.8$ ;  $df = 1$ ,  $p > 0.05$ ). The average age of the patients was  $48.5 \pm 14.37$  years; the youngest patient was 21 and the oldest 75 years. The distribution of the age variable was normal, which allowed the use of parametric tests.

Analysis of age in relation to gender showed no statistically significant difference in age between male and female ( $t = 0.048$ ,  $df = 18$ ;  $p > 0.05$ ).

In all the patients unilateral hearing loss was present. Analyzing body sides, no statistically significant difference was recorded ( $= 0.2$ ;  $df = 1$ ;  $p > 0.05$ ), the right-sided hearing loss was diagnosed in 11 (55%) and sinistral in 9 (45%) patients.

In addition to hearing loss, we observed other symptoms (Table 1). The most common symptom was second tinnitus, present in 9 (45%) patients. Vertigo was present in 7 (35%). Without hearing impairment in addition to other symptoms there were 4 patients (20%).

Distribution of respondents according to the degree of hearing impairment is shown in Table 1. There was no statistically significant difference in the degree of hearing impairment in the analyzed sample ( $= 6.8$ ,  $df = 3$ ;  $p > 0.05$ ).

Distribution of respondents according to the shape of audiometric curves is given in Table 1. For most respondents, 15 (75%), audiometric curve was porcine descending type, and  $\chi^2$  test showed that the difference in the number of patients due to the type of curves was statistically highly significant ( $= 26.8$ ;  $df = 3$ ;  $p < 0.01$ ) in favor of a downward curve.

Upon completion of the entire treatment protocol with HBO therapy 11 (55%) patients had a complete recovery of hearing (final hearing threshold above 25 dB). A partial recovery (hearing aids of up to 15 dB and a final hearing threshold below 45 dB) was achieved in 4 (20%) patients. There was no hearing improvement or it was less than 5 dB in 5 (25%) patients, of which one respondent (5%) had a complete loss of hearing.

The average ITH of all the patients at all frequencies (500; 1,000, 2,000 and 4,000 Hz) was 60.04 dB, while the average FTH was 35.10 dB (Table 2).

The average absolute hearing recovery of all the patients at all frequencies amounted to 24.94 dB. The average relative improvement in hearing of all the patients at all frequencies amounted to 65.45% (Table 3).

**Table 1**  
**Clinical characteristics of patients with sudden sensorineural hearing loss**

Characteristics	Number (%) of patients
Symptoms	
partial hearing loss	20 (100)
tinnitus	9 (45)
vertigo	7 (35)
none	4 (20)
Degree of hearing impairment	
easy (< 40 dB)	4 (20)
mild (41–60 dB)	9 (45)
hard (61–80 dB)	6 (30)
deftness (> 80 dB)	1 (5)
Shape of audiometric curve	
horizontal	2 (10)
descending	15 (75)
recessed	2 (10)
deftness curve	1 (5)

Table 2

Hearing threshold prior and after the therapy										
Hearing threshold	500 Hz	<i>p</i>	1000 Hz	<i>p</i>	2000 Hz	<i>p</i>	4000 Hz	<i>p</i>	Average	<i>p</i>
Initial (dB)	33.25	0.000	58.75	0.000	69.47	0.000	78.68	0.000	60.04	0.000
Final (dB)	22.75		34.75		39.74		43.16		35.10	

Table 3

Hearing improvement after the therapy					
Hearing improvement	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
Absolute (dB)	10.50	24.00	29.73	35.52	24.94
Relative (dB)	79.25	61.94	60.10	60.53	65.45

T-test for related samples demonstrated a highly statistically significant difference ( $p < 0.001$ ) in the threshold of hearing on audiogram before and after oxygen therapy at four frequencies (500, 1,000, 2,000 and 4,000 Hz), which speaks to the fact that the application of HBO treatment of sudden hearing impairment gives good results.

### Discussion

The etiology of sudden sensorineural hearing loss has not yet been fully tested. Experimental studies have shown that the most common pathological changes are found in the striatum vascularis (capillaries are longer and of narrower lumens, causing decreased blood stream at the threshold of hypoxia). The use of medications that increase the perfusion of the inner ear (the percentage of oxygen, glucose utilization) allows cells the organ of Corti to survive until the restoration of normal conditions for the function<sup>7</sup>.

In this study, hearing improvement after the therapy was defined as a decrease in the threshold of the pure tone of 10 dB or more at four frequencies (500, 1,000, 2,000 and 4,000 Hz), regardless of the level of hearing loss at the beginning<sup>1</sup>.

The Siegel classification is based on the significance of the initial hearing loss, as the recovery of, for example, 20 dB does not have the same significance when it occurs at the level between 25 and 40 dB, or at the level of over 45 dB<sup>10</sup>.

According to the classification that was used in this study to assess the success of treatment with HBO, for the effectiveness of the therapy is used an average increase (in dB) at four speech audiometric frequencies (500, 1,000, 2,000 and 4,000 Hz)<sup>1</sup>.

It was pointed out that the initial degree of hearing loss is very important prognostic indicator for the outcome of the treatment of sudden hearing loss<sup>11</sup>.

Although the results of most studies suggest that therapy should begin as soon as possible<sup>11, 12</sup>, some authors believe that acute hearing loss is not a medical emergency

and treatment is not necessary to start in the first 24 h, but in the first 7 days<sup>13</sup>.

Comparing the two ways of treating patients with sudden deafness – vasoactive agents and corticosteroids, lead to the conclusion that the use of vasoactive agents offers clinically evident improvements, and corticosteroids a greater percentage of early recovery of hearing<sup>14</sup>.

Also, comparison of the two ways of treating patients with sudden deafness (HBO and pentoxifylline), shows that in the group of patients treated with HBO hearing improvement was statistically significantly higher than in the group of patients treated with infusions of pentoxifylline<sup>15</sup>.

Similarly, in a Pezzoli et al.<sup>16</sup> study hearing improvement was significantly greater in patients treated with HBO compared to the control group (patients not treated).

Comparison of the results of co-administration of HBO and drug therapy on the one hand, and the only drug therapy on the other, shows that significantly better results are achieved in patients treated with combination therapy than in those treated only with drug therapy<sup>17</sup>.

Analysis of possible therapy protocols, after the cessation of the effect of treatment with systemic corticosteroids, shows that the application of HBO and intratympanic instillation of corticosteroids can be life-saving in these patients<sup>18</sup>.

Studies show that HBO addition to usual treatment significantly improves the outcome of idiopathic sudden sensorineural hearing loss<sup>19</sup>.

### Conclusion

Due to unclear multifactorial etiopathogenesis of sudden sensorineural hearing loss there are many therapeutic protocols. Further prospective clinical trials are expected to come to the conclusion which method of treatment or combination therapy protocols should be given priority. Based on the results of our study hyperbaric oxygen can be recommended as primary treatment of sudden sensorineural hearing loss.

## R E F E R E N C E S

1. Živić LJ, Živić Đ, Stojanović S. Sudden hearing loss: Our experience in the treatment with vasoactive agents. *Srp Arh Celok Lek* 2008; 136(3-4): 91-4.
2. Rambold H, Boenki J, Stritzke G, Wisst F, Neppert B, Helmchen C. Differential vestibular dysfunction in sudden unilateral hearing loss. *Neurology* 2005; 64(1): 148-51.
3. Shemirani NL, Schmidt M, Friedland DR. Sudden sensorineural hearing loss: An evaluation of treatment and management approaches by referring physicians. *Otolaryngol Head Neck Surg* 2009; 140(1): 86-91.
4. Xenellis J, Nikolopoulos TP, Stavroulaki P, Marangoudakis P, Andronlakis M, Tsangaroulakis M, et al. Simultaneous and sequential bilateral sudden sensorineural hearing loss: Are they different from unilateral sudden sensorineural hearing loss. *ORL J Otorhinolaryngol Relat Spec* 2007; 69(5): 306-10.
5. Maslovara S. The primary treatment of idiopathic sudden hearing loss with oxygen under high pressure [thesis]. Zagreb: Faculty of Medicine, University of Zagreb; 1999. (Croatian)
6. Hughes GB, Freedman MA, Haberkamp TJ, Guay ME. Sudden sensorineural hearing loss. *Otolaryngol Clin North Am* 1996; 29(3): 393-405.
7. Mihailović-Kokić B, Todorović AJ, Kokić Z. Acute deafness-personal experience with therapy. *Srp Arh Celok Lek* 2002; 130(11-12): 394-6. (Serbian)
8. Furuhashi A, Matsuda K, Asabi K, Nakashima T. Sudden deafness: Long-term follow-up and recurrence. *Clin Otolaryngol Allied Sci* 2002; 27(6): 458-63.
9. Žinković M. Manual for Hyperbaric Medicine. Belgrade: Srpska zdravstvena organizacija; 2010. (Serbian)
10. Siegel LG. The treatment of idiopathic sudden sensorineural hearing loss. *Otolaryngol Clin North Am* 1975; 8(2): 467-73.
11. Byl FM. Sudden hearing loss: Eight years' experience and suggested prognostic table. *Laryngoscope* 1984; 94(5 Pt 1): 647-61.
12. Shaia FT, Sheehy JL. Sudden sensori-neural hearing impairment: A report of 1,220 cases. *Laryngoscope* 1976; 86(3): 389-98.
13. Čvorović LJ, Đerić D, Pavićević LJ, Probst R, Hegemann S. Does acute sensorineural deafness befall to urgent conditions? *Vojnosanit Pregl* 2009; 66(1): 35-8. (Serbian)
14. Živić LJ, Živić Đ, Đonović N. Sudden hearing loss: Our experience in the treatment with vasoactive agents and corticosteroid drugs. *Srp Arh Celok Lek* 2012; 140(3-4): 153-8.
15. Racić G, Maslovara S, Roje Z, Dogas Z, Tajfra R. Hyperbaric Oxygen in the Treatment of Sudden Hearing Loss. *ORL J Otorhinolaryngol Relat Spec* 2003; 65(6): 317-20.
16. Pezžoli M, Magnano M, Maffi L, Pezžoli L, Marcato P, Orione M, et al. Hyperbaric oxygen therapy as salvage treatment for sudden sensorineural hearing loss: a prospective controlled study. *Eur Arch Otorhinolaryngol* 2015; 272(7): 1659-66.
17. Dundar K, Gumus T, Ay H, Yetiser S, Ertugrul E. Effectiveness of hyperbaric oxygen on sudden sensorineural hearing loss: Prospective clinical research. *J Otolaryngol* 2007; 36(1): 32-7.
18. Čvorović LJ, Jovanović MB, Milutinović Z, Arsović N, Djerić D. Randomized prospective trial of hyperbaric oxygen therapy and intratympanic steroid injection as salvage treatment of sudden sensorineural hearing loss. *Otol Neurotol* 2013; 34(6): 1021-6.
19. Topuz E, Yigit O, Cinar U, Seven H. Should hyperbaric oxygen be added to treatment in idiopathic sudden sensorineural hearing loss. *Eur Arch Otorhinolaryngol* 2004; 261(7): 393-6.

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