

# Pretreatment hearing grades and hearing recovery outcomes after primary hyperbaric oxygen treatment in patients with idiopathic sudden sensorineural hearing loss

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## Keywords

Clinical audit; Deafness; ENT; Hyperbaric research; Otorhinolaryngology, Outcome

## Abstract

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**Introduction:** Previous studies suggest the effectiveness of hyperbaric oxygen treatment (HBOT) in idiopathic sudden sensorineural hearing loss (ISSNHL) but it is mostly used as an adjuvant and salvage treatment. This study evaluated the effect of primary HBOT according to pretreatment hearing grades and hearing recovery outcomes using modified Siegel's criteria in patients with ISSNHL.

**Methods:** Fifty-nine ISSNHL patients treated with only HBOT were included. A pure-tone audiogram was recorded before and after a course of HBOT (90 min at 203 kPa daily for 20 days). Using the modified Siegel's criteria, patients were divided into groups according to hearing threshold before and after treatment.

**Results:** Hearing thresholds were significantly lower after HBOT compared to pre-treatment values across all patients ( $P < 0.001$ ) with a median value of recovery of 22.5 dB (interquartile range 12.5–33.7 dB). Significantly lower hearing threshold values were recorded at 500, 1,000, 2,000, and 4,000 Hz after treatment ( $P < 0.001$ ). The greatest recovery was at 1,000 Hz, (change in median threshold = 32 dB) but without a significant difference compared to other frequencies ( $P = 0.10$ ).

**Conclusions:** HBOT is a legitimate choice as the primary treatment for ISSNHL, especially if it is readily accessible, and if there are contraindications for corticosteroid therapy.

## Introduction

Idiopathic sudden sensorineural hearing loss (ISSNHL) is a medical emergency, defined as hearing loss greater than 30 dB over at least three consecutive frequencies, and that develops within three days.<sup>1,2</sup> In addition to hearing loss, this condition can be accompanied by vertigo, tinnitus, and a feeling of ear congestion. The annual incidence is approximately five to 20 cases per 100,000.<sup>3</sup> Numerous potential causes of sudden hearing loss are listed in the literature, such as infectious, vascular, traumatic, toxic, neurological, metabolic, and neoplastic, but in 85% of cases, the cause cannot be determined and is thus 'idiopathic'.<sup>4</sup> Due to the variety of causes, the high percentage of idiopathic cases, and the occurrence of spontaneous recovery in up to 65% of cases, choice of treatment and evaluation of treatment efficacy in sudden sensorineural hearing loss is challenging.<sup>3</sup> Various treatments have been proposed and applied worldwide. According to the latest clinical practice

guideline from 2019, corticosteroids are recommended as first-line therapy for ISSNHL and intratympanic application of corticosteroids may be used as rescue therapy.<sup>5</sup> There are many studies of the use of corticosteroids, but there is limited evidence of their efficacy and there may be adverse effects.<sup>1</sup> A Cochrane systematic review does not suggest definitive efficacy of oral corticosteroids,<sup>6</sup> and another recent review suggests no significant difference in hearing recovery between patients treated or not treated with corticosteroids.<sup>7</sup>

Idiopathic sudden sensorineural hearing loss can also be treated with hyperbaric oxygen treatment (HBOT). The use of HBOT in ISSNHL is based in part on the notion that compromised vascular supply and consequent cochlear ischaemia contribute to the development of sudden hearing loss. In addition, inflammatory and other mechanisms are also mentioned among the possible causes of ISSNHL;<sup>6</sup> these pathophysiological processes are also potentially modified by HBOT. Numerous studies suggest benefit

from HBOT,<sup>8–12</sup> but it is mostly promoted as an adjuvant or salvage treatment for ISSNHL. Several studies suggest that the greatest recovery is achieved in combination with corticosteroids.<sup>10–12</sup> Only a few studies mention the use of HBOT as primary therapy for ISSNHL,<sup>5</sup> and there has been demonstration of apparent efficacy in this setting.<sup>12</sup> It is relevant that the only treatment for ISSNHL that has had a cautiously positive Cochrane review (in 2012)<sup>13</sup> is HBOT and this was used to justify the inclusion of ISSNHL as a clinical indication for HBOT by Undersea and Hyperbaric Medical Society in 2014.

Despite the latter, corticosteroid therapy remains the most widely accepted primary treatment for ISSNHL, and the efficacy of HBOT in comparison to other forms of treatment requires further research. A related problem is the lack of a universal system for assessing the effectiveness of therapy, which would greatly help in comparing the results of numerous scientific papers on this topic. One of the most commonly used systems for presenting recovery is Siegel's criteria. Recently, modified Siegel's criteria for ISSNHL have been presented, which also include pretreatment hearing grades for better prognostic assessment.<sup>14</sup> This study aimed to evaluate the effect of HBOT according to modified Siegel's criteria in patients with ISSNHL.

## Methods

The study was approved by the ethics committee of the Clinical Hospital Centre Osijek (Approval No. 158-51-04-15-06).

A total of 59 patients treated for ISSNHL with HBOT in the period from January 2015 to the end of December 2019 were included in this retrospective study. Patients were offered various treatments for ISSNHL, and the patients included in this study were those who refused corticosteroid therapy. The most common reasons for refusing other forms of treatment were fear of side effects and diagnosis of diabetes. We recorded demographic data, level of hearing loss before and after treatment, time from onset of symptoms to the onset of treatment, as well as the presence of tinnitus and vertigo. Only patients with sudden sensorineural hearing loss of idiopathic cause were included. Exclusion criteria were age under 18, diagnosis of Meniere's disease, brain tumor, acoustic trauma, bilateral hearing loss, barotrauma, chronic otitis media, history of ear surgery, failure to obtain a pure-tone audiogram after treatment, and receipt of another form of therapy primarily or adjvantly.

A pure-tone audiogram was recorded in all patients during the first visit to the otorhinolaryngologist and after completion of the HBOT course. Hearing thresholds and hearing loss were calculated according to the average hearing threshold at the four frequencies (500, 1,000, 2,000, and 4,000 Hz). According to the modified Siegel's criteria,<sup>14</sup> patients were divided into groups before treatment according to the hearing threshold, and according to recovery after

HBOT. Pretreatment hearing grades were grade one (hearing threshold < 25 dB), grade two (hearing threshold 26–45 dB), grade three (hearing threshold 46–70 dB), grade four (hearing threshold 71–90 dB) and grade five (hearing threshold > 90 dB). The following recovery groups after HBOT were determined according to modified Siegel's criteria: complete recovery (final hearing threshold < 25 dB), partial recovery (improvement > 15 dB and final hearing threshold 25–45 dB), slight recovery (improvement > 15 dB, final hearing threshold > 45 dB), no improvement (improvement < 15 dB, final hearing threshold 76–90 dB) and non-serviceable ear (final hearing threshold > 90 dB).

## HBOT PROTOCOL

Hyperbaric oxygen treatment was administered in a multiplace hyperbaric chamber, in which patients inhaled pure medical (100%) oxygen on a mask, at a pressure of 203 kPa (2 atmospheres absolute) for 90 minutes. Each treatment consisted of three phases: compression of the chamber over 15 minutes, oxygen inhalation under pressure for one hour, and depressurisation of the chamber over 15 minutes. The procedure was performed once daily, for 20 days.

## STATISTICAL ANALYSIS

Data were analysed using SPSS Statistics for Windows (IBM Corp. Armonk, NY, USA). Differences in categorical variables or proportions were tested by the Chi-square test. The normality of the distribution of continuous variables was tested by the Shapiro-Wilk test and non-parametric analyses were applied. Differences between two independent groups were tested by the Mann-Whitney U test, and for three or more groups by the Kruskal-Wallis test (Dunn correction). The correlation of continuous variables was estimated by the Spearman correlation coefficient  $\rho$  (rho). All *P*-values were two-sided. The significance level was set to  $\alpha < 0.05$ .

## Results

A total of 59 patients (31 males and 28 females, median age 56 years, interquartile range [IQR] 48–65 years) with ISSNHL were included in the study.

The median time from the onset of symptoms to treatment was three days (IQR 2–7 days). According to the modified Siegel's criteria and hearing thresholds before HBOT there were no grade one patients, three (5.1%) grade two patients, 14 (23.7%) grade three patients, 18 (30.5%) grade four patients and 24 (40.7%) grade five patients.

Following HBOT, hearing loss was significantly reduced with the median loss across all frequencies falling from 81.2 dB (IQR 70.0–95.0) to 58.1 dB (IQR 47.5–77.5) ( $P < 0.001$ ). The difference in the median value of hearing loss before and after HBOT across all patients was 22.5 dB (IQR 12.5–33.75). Significantly lower

**Table 1**

Median hearing threshold before and after HBOT ( $n = 59$ ) at four frequencies;  $P < 0.001$  for all before / after comparisons; dB – decibel; Hz – Hertz; HBOT – hyperbaric oxygen treatment; IQR – interquartile range

Frequency (Hz)	Threshold (dB) Median (IQR)	
	Before HBOT	After HBOT
500	74 (55–95)	42.2 (25–60)
1,000	83 (70–100)	50.8 (20–70)
2,000	84 (65–100)	58.6 (45–80)
4,000	87 (70–100)	66 (55–80)

**Table 2**

Recovery in hearing thresholds (difference between before and after HBOT) at all frequencies ( $n = 59$ ); dB – decibel; Hz – Hertz; IQR – interquartile range

Recovery (dB) before to after HBOT Median (IQR)	Frequency				<i>P</i>
	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	
	25 (10–50)	30 (15–45)	20 (10–40)	20 (10–5)	

**Table 3**

Recovery category after HBOT stratified by pretreatment hearing grades; data are number of patients; HBOT – hyperbaric oxygen treatment

Grade before HBOT	Recovery category after HBOT				Total	<i>P</i>
	Complete recovery	Partial recovery	Slight recovery	No improvement		
Grade two	0	0	0	3	3	0.003
Grade three	3	3	3	5	14	
Grade four	2	0	5	11	18	
Grade five	0	1	17	6	24	
Total	5	4	25	25	59	

hearing thresholds were observed at 500, 1,000, 2,000 and 4,000 Hz after treatment, with the largest difference at 1,000 Hz (Table 1) but without a significant difference compared to other frequencies (Table 2).

Most of the patients after HBOT were in the slight recovery and no improvement groups. There were no patients in the non-serviceable ear group. Most patients in the no improvement group belonged to pretreatment grade four, and most of the patients in the group of complete recovery were in grade three before treatment (Table 3).

There were four patients who started HBOT greater than 14 days from the onset of symptoms. The median value of hearing recovery (difference in hearing thresholds before and after HBOT) was 17.5 dB (IQR 4.1–38.4), and the median hearing threshold after HBOT was 54.3 dB (IQR 51.8–68.1) for these ‘delayed’ patients. There was no significant difference in recovery (difference in hearing

threshold before and after HBOT) between patients who started therapy within seven days, 7–14 days, or > 14 days from the onset of symptoms ( $P = 0.39$ ). There was no association between treatment initiation time and recovery (Spearman’s Rho = 0.08;  $P = 0.52$ ).

Significantly more patients in Siegel’s grades four (6/18) and five (8/24) had tinnitus and vertigo ( $P = 0.04$ ). There was no significant difference in the presence or absence of tinnitus and vertigo with regard to the recovery group ( $P = 0.9$ ), although tinnitus and vertigo were most common in patients in the slight (8/25) and no improvement groups (9/25).

**Discussion**

This retrospective study aimed to show the effect of HBOT as primary therapy in patients with ISSNHL classified according to modified Siegel’s criteria. There was a significant reduction in the median hearing loss across all frequencies

with the median threshold falling from 81.2 dB to 58.1 dB; a median difference of 22.5 dB. The study group seemed consistent with the known demographics of ISSNHL. There were slightly more men (52.5%) than women. According to the literature, the representation of ISSNHL by gender is equal, and the most exposed age group is between 50 and 60 years, which is consistent with our data.<sup>1,15</sup>

There is evidence that hearing loss in low and mid-frequencies has a better prognosis.<sup>16,17</sup> In the present study, the largest difference in median hearing threshold before and after HBOT, i.e., the largest recovery, was at 1,000 and 500 Hz, but without a significant difference compared to other frequencies (Table 2). A possible explanation for the greatest recovery at lower frequencies might be the difference in the vulnerability of hair cells. Hair cells in the basal part of the cochlea that detects high frequencies are more sensitive to damage than those found in the apex, so damage to the basal part has a worse prognosis.<sup>7,17,18</sup>

According to the modified Siegel's criteria, patients were divided into five pretreatment hearing loss grades and five post-HBOT grades based on the final hearing thresholds and improvement. Most patients were in grade five before HBOT (Table 3), meaning that most patients had a hearing threshold > 90 dB, and after HBOT most patients were in the slight and no improvement groups, which agrees with the data from the literature that says that greater hearing loss predicts less recovery.<sup>19–22</sup> More patients in grade three achieved complete recovery compared to other groups of patients, while in the no improvement group there were more patients from grade four (Table 3). The three patients in grade two pre-HBOT all fell into the no improvement group after HBOT. According to the Cochrane systematic review from 2012, patients with moderate and severe hearing loss have the greatest recovery after using HBO,<sup>13</sup> which is consistent with our results. Similarly, other studies demonstrated the best recovery in pretreatment grade three,<sup>14</sup> or in patients with hearing loss > 61 dB.<sup>23</sup>

Among the negative prognostic factors for recovery a longer delay to initiation of treatment is considered important.<sup>4,19,20,22</sup> Hearing recovery outcomes are thought to be better if HBOT is started within two weeks from the onset of symptoms.<sup>5,13</sup> In the present study the median delay from the onset of symptoms to the start of treatment was three days (IQR 2–7). Delays were divided into three groups (< 7 days, 7–14 days, > 14 days), and no significant difference was found in recovery with respect to the time of the beginning of therapy. Given that it is recommended to start therapy within two weeks, the group of patients who started after 14 days from the onset of symptoms was of particular interest. These four patients had a median hearing threshold after HBOT of 54.3 dB and a median threshold recovery of 17.5 dB. These patients belonged to the slight improvement group after HBOT, therefore it is still possible to improve the hearing threshold with HBO as primary therapy even after 14 days.

Vertigo and tinnitus occur in 40% of patients with ISSNHL, and they are considered a negative predictive factor for recovery,<sup>24</sup> although there are dissenting opinions.<sup>22</sup> In the present study there was no clear difference in the presence or absence of symptoms of tinnitus and vertigo with regard to recovery after HBOT, but tinnitus and vertigo were still present in larger numbers in patients with slight and no improvement group.

In the available literature, HBOT is commonly used as adjuvant therapy, and according to guidelines, corticosteroids are recommended as primary therapy.<sup>5</sup> Corticosteroids are thought to achieve hearing improvement in ISSNHL by suppressing the immune system, improving microcirculation, reducing inflammation, and oedema.<sup>25,26</sup> The hyperoxygenation achieved with HBOT has a similar effect. Hyperoxygenation stimulates neovascularisation, vasoconstriction and reduces local oedema, and also alters the levels of proinflammatory mediators.<sup>27–29</sup> Due to a similar mechanism of action, and taking account of the present results, we suggest that HBOT can be used as the primary treatment for ISSNHL. HBOT has the advantage of minor side effects compared to corticosteroid therapy, albeit with greater cost and logistic difficulties. The logistic ease of providing HBOT in this study can be attributed to the good cooperation of our institution with the polyclinic that conducts HBOT locally, the treatments being covered by the patient's health insurance, and the regular attendance of patients for treatments.

#### LIMITATIONS

The principle limitation of this study is the lack of a comparator group primarily treated with corticosteroids that would allow comparison of outcomes with those obtained using HBOT. Similarly, the known potential for some ISSNHL cases to improve spontaneously in the absence of treatment limits our ability to confidently attribute all measured recovery to HBOT. The study is also small and retrospective in design. Prospective research with control groups should certainly be conducted and without such definitive studies inconsistent adoption of HBOT in ISSNHL is likely to continue.<sup>30</sup> Despite these limitations, the results of this study provide qualified support for the use of HBOT as primary therapy, and as well as an incentive for further research.

#### Conclusions

Hyperbaric oxygen therapy is an acceptable and promising choice as the primary treatment for ISSNHL, especially if it can be provided with logistical ease, and if there are no contraindications or relative contraindications for corticosteroid therapy.

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