



Hyperbaric oxygen therapy: The last remedy for sudden sensorineural hearing loss?

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ABSTRACT

Objectives: This study aims to evaluate hyperbaric oxygen (HBO) therapy as a salvage treatment option for sudden sensorineural hearing loss (SSNHL) and analyze factors influencing treatment outcomes.

Patients and Methods: Charts of 27 patients (20 males, 7 females; mean age 50.8 years; range, 30 to 74 years) who received HBO therapy as salvage treatment were retrospectively evaluated between January 2007 and December 2017. Patients' demographics, time between onset of SSNHL to the initiation of steroid and HBO treatments, audiogram curves, tinnitus, vestibular symptoms, and pure tone audiometry results before and after steroid and HBO therapies were evaluated. Siegle's criteria were used to evaluate treatment outcomes.

Results: According to Siegle's criteria, while seven patients had slight improvement, partial improvement was seen in two patients. With HBO therapy, a statistically significant improvement was seen at 250, 500, and 8000 Hz frequencies. Diabetes mellitus and patients' age were related with treatment outcomes.

Conclusion: Hyperbaric oxygen therapy may be beneficial as a salvage treatment option in some patients. Better results may be expected particularly in young and non-diabetic patients.

Keywords: Hearing loss, hyperbaric oxygen, sensorineural.

Sudden sensorineural hearing loss (SSNHL) is an otologic emergency defined as a sensorineural hearing loss more than 30 dB encompassing three consecutive frequencies occurring within three days.^[1] Different theories such as vascular compromise, membrane rupture, autoimmunity, and viral etiology have been accused in the development of SSNHL.^[1-3] Systemic and/or local corticosteroid administration is the most widely accepted treatment modality. Different agents

such as antivirals, diuretics, plasma expanders, and hyperbaric oxygen (HBO) therapy have also been proposed.^[1-4]

Regardless of the etiology, decreased cochlear blood flow and cellular hypoxia were considered as the main pathological mechanisms of SSNHL. Hyperbaric oxygen therapy was postulated to help the recovery of SSNHL by increasing inner ear oxygenation. In this study, we aimed to

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evaluate HBO therapy as a salvage treatment option for SSNHL and to analyze factors influencing treatment outcomes.

PATIENTS AND METHODS

Charts of 157 patients treated in Dokuz Eylül University, Faculty of Medicine, Department of Otorhinolaryngology for SSNHL between January 2007 and December 2017, of whom 45 had failed corticosteroid therapy, were retrospectively evaluated. Among these, 27 patients (20 males, 7 females; mean age 50.8 years; range, 30 to 74 years) accepted HBO therapy as a salvage treatment and their data were collected. Patients' demographics, initial treatment properties, time from the onset of SSNHL to initiation of steroid and HBO therapy, initial audiogram curves, absence or presence of tinnitus and vestibular symptoms, and pre- and post-treatment audiological results for steroid and HBO therapies were evaluated. The study protocol was approved by the Dokuz Eylül University, Faculty of Medicine Ethics Committee for non-invasive research (2018/20-06). A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients received oral methylprednisolone 1 mg/kg for five days, then the steroid dose was gradually tapered and treatment was ended in 10-15 days depending on the weight of the patient. Intratympanic (IT) dexamethasone (4 mg/mL) injections for 10 days (once a day) were also performed if the initial mean hearing threshold was worse than 50 dB or worsened despite systemic steroid therapy. Hyperbaric oxygen therapy was proposed as a salvage treatment option in case of steroid therapy failure. These patients were treated in a HBO chamber at a pressure of 2.2 atmospheres for 90 minutes per day for 20 days.

Pure tone, speech audiometry, and tympanometry tests were performed in all patients. The pure tone average was calculated by using the 500, 1000, 2000, and 4000 Hz thresholds. Pure tone audiometry results obtained just before and just after the ending of HBO therapy were used to analyze the treatment outcomes.

Treatment success was evaluated according to the Siegel's criteria.^[5] If the patients' final mean hearing thresholds were better than 25 dB, it was accepted as "complete recovery"; while in case of a hearing gain more than 15 dB with final hearing thresholds between 25 and 45 dB, the recovery was accepted as "partial". A hearing gain more than 15 dB with final hearing thresholds below 45 dB was considered as a "slight improvement", while hearing gain less than 15 dB and final hearing thresholds poorer than 75 dB at the end of treatment were considered as "no improvement".

Apart from Siegel's criteria, a frequency specific analysis was also conducted and the mean hearing thresholds at 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz prior to and after HBO therapy were analyzed.

Patients' age, timing of HBO therapy, hypertension, diabetes mellitus (DM), tinnitus and vertigo, and initial audiogram configuration were evaluated.

To analyze the possible effects of patients' age on the treatment outcome, "50" was chosen as a cut off age which was the case in many similar studies.^[1,6,7] To analyze the effect of timing of HBO therapy, patients were divided into two groups: Those who received HBO therapy within the first 15 days were classified as the early treatment group (n=11) and the rest of the patients were classified as the late treatment group (n=16).

Statistical analysis

The SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses and $p < 0.05$ was accepted as a statistically significant difference for all comparisons. Chi-square and Fischer's exact tests were used for the analyses of factors associated with treatment success. For the comparison of specific frequencies, Wilcoxon signed-rank test was used.

RESULTS

All but three patients had oral methylprednisolone and IT dexamethasone treatments prior to HBO therapy. In nine patients (33.3%), hearing improvement was observed according to the Siegel's criteria. In seven patients (25.9%), this improvement was slight and two patients (7.4%) had partial improvement

Table 1. Hyperbaric oxygen therapy outcomes according to Siegle's criteria

| Recovery | Number of patients |
|--------------------|--------------------|
| Complete recovery | 0 |
| Partial recovery | 2 |
| Slight improvement | 7 |
| No improvement | 18 |

with HBO therapy. No improvement was seen in 18 patients (66.6%) (Table 1).

The mean hearing thresholds before and after corticosteroid therapy were 87.2±17.1 dB and 79.8±16.5 dB, respectively. At the end of HBO therapy, the mean hearing threshold was 69.7±18.5 dB. According to frequency specific analyses, the mean hearing thresholds were significantly improved at 250 Hz, 500 Hz, and 8,000 Hz frequencies (Table 2).

Seventeen patients were older than 50 years and the remaining 10 were younger. Our univariate analyses showed that the success of HBO therapy was related to the age of the patient ($p < 0.05$, Table 3) and patients younger than 50 years had better outcomes.

Diabetes mellitus in two, hypertension in five, and both DM and hypertension in six patients were determined as risk factors. According to our statistical analyses, DM was associated with poorer HBO therapy responses ($p < 0.05$, Table 3) while no significant relationships were found between hypertension and HBO therapy

outcomes ($p > 0.05$, Table 3). Tinnitus was present in 25 patients and 11 patients had vestibular symptoms. None of these two symptoms was correlated with the HBO treatment success ($p > 0.05$, Table 3).

The mean times from the onset of SSNHL to the beginning of steroid treatment and HBO therapy were 4.9 days (range, 1-15 days) and 21.1 days (range, 11-31 days), respectively. In 11 patients, HBO therapy was administered in the first 15 days following the onset of the symptoms. Sixteen patients received HBO therapy between 16 to 31 days after the occurrence of SSNHL. The timing of HBO therapy had no effects on the treatment success ($p > 0.05$, Table 3).

In 20 out of 27 patients, the audiogram curve was flat, while a down-sloping curve was seen in seven of them. No statistically significant differences were found between the types of the audiogram curve and treatment outcome ($p < 0.05$, Table 3).

DISCUSSION

Sudden sensorineural hearing loss is an otologic emergency affecting 5 to 20 individuals per 100,000 population per year.^[1] Many different options including systemic/IT steroids, antiviral agents, diuretics, rheologic agents, and HBO therapy were proposed as first line of treatments.^[1] Although SSNHL requires urgent intervention, spontaneous recovery rates varying between 32 to 65% have been reported.^[1,8]

Table 2. Mean hearing thresholds before and after hyperbaric oxygen therapy

| Frequency | Mean hearing thresholds before hyperbaric oxygen therapy | Mean hearing thresholds after hyperbaric oxygen therapy | <i>p</i> |
|-----------|--|---|--------------|
| | Mean±SD | Mean±SD | |
| 250 Hz | 69.6±24.8 | 50±25.9 | 0.02 |
| 500 Hz | 75.4±22.7 | 60±25.1 | 0.02 |
| 1,000 Hz | 81.1±15.5 | 74.4±25.5 | >0.05 |
| 2,000 Hz | 84.4±18.6 | 78.5±23.3 | >0.05 |
| 4,000 Hz | 89.8±21.0 | 84.4±24.4 | >0.05 |
| 8,000 Hz | 91.9±19.8 | 85.7±19.8 | 0.014 |

SD: Standard deviation.

Table 3. Analysis of factors influencing treatment outcomes

| | Number of patients | Number of patients with hearing improvement | Number of patients without hearing improvement | <i>p</i> |
|--|--------------------|---|--|--------------|
| Patients under 50 years old | 10 | 7 | 3 | 0.046 |
| Patients over 50 years old | 17 | 2 | 15 | |
| Diabetes mellitus | 8 | 0 | 8 | 0.026 |
| Hypertension | 11 | 2 | 9 | >0.05 |
| Days prior to hyperbaric oxygen therapy (<15 days) | 11 | 3 | 8 | |
| Days prior to hyperbaric oxygen therapy (>15 days) | 16 | 6 | 10 | >0.05 |
| Patients with vestibular symptoms | 11 | 4 | 7 | |
| Patients without vestibular symptoms | 16 | 5 | 11 | >0.05 |
| Patients with tinnitus | 24 | 8 | 16 | |
| Patients without tinnitus | 3 | 1 | 2 | >0.05 |
| Flat type audiogram | 20 | 7 | 13 | |
| Down-sloping type audiogram | 7 | 2 | 5 | >0.05 |

Systemic corticosteroid therapy is generally considered as the first line treatment option for SSNHL.^[1,2] Intratympanic injections are mostly used as salvage treatments.^[1,4,9] However, good recovery rates have also been reported with IT steroid injections alone^[10] or its combination with systemic steroid therapy.^[11,12] In our institution, we routinely use systemic or systemic and IT corticosteroid combination to treat SSNHL.

Since we consider HBO therapy as a salvage treatment option, the majority of our patient group (24 out of 27) consisted of cases in which both systemic and IT steroid treatments failed. Hyperbaric oxygen therapy led to some degree of hearing improvement in nine out of 27 patients (33%). In seven patients (25.9%), this improvement was slight while a partial improvement was seen in two patients (7.4%).

Similar improvement rates were reported in different studies. In a study conducted by Horn et al.,^[13] HBO was used as a salvage therapy and it was reported that two out of nine patients had dramatic improvements in hearing thresholds and one patient had some amelioration in his speech discrimination score. Pezzoli et al.,^[14] evaluated the efficacy of HBO

treatment as a salvage option. In that study, patients unresponsive to corticosteroid therapy were divided into control and HBO groups. In the HBO group, varying degrees of hearing improvement was seen in 16 out of 23 patients, while only four of 21 patients recovered in the control group. Another similar study reported complete recovery in three patients and partial or slight recovery in six patients, while 25 patients had no improvements.^[15]

Yang et al.^[4] compared different salvage therapy options including IT steroids, HBO therapy, and their combinations. It was found that both IT corticosteroid and HBO treatments were effective in terms of salvage without any statistically significant differences while their combination led to a larger rate of hearing improvement.^[4] In another similar study comparing treatment outcomes of HBO therapy and IT injections, better hearing recovery at 8,000 Hz and better improvements in tinnitus symptoms were seen in the IT steroid groups.^[9]

The efficacy of HBO treatment is generally more prominent at lower frequencies; Ajduk et al.,^[3] reported that 250 Hz and 500 Hz frequencies were significantly improved

after HBO therapy as a salvage treatment. Also, other studies concluded that hearing gains obtained with HBO or other salvage therapy options decreased towards the higher frequencies.^[4,16,17] This finding may be related to the fact that the basal turn of the cochlea is more vulnerable to damage, thus rendering it harder to recover from the previous injuries.^[4] In our study, we obtained similar findings: Hearing thresholds were significantly improved at 250 and 500 Hz frequencies. Surprisingly, we found a statistically significant improvement at 8,000 Hz as well. We think that this may be a coincidental finding due to our relatively low number of patients.

Many different factors have been reported to influence SSNHL. While hypertension and DM have been generally accepted as bad prognostic factors,^[1,2,18] in some studies, their existence was found not to be related with the treatment outcome.^[19,20] In our study, we also evaluated the possible effects of these diseases on the treatment outcome and found a statistically significant relationship between DM and poor treatment outcomes ($p=0.026$). None of our eight DM patients recovered despite salvage therapy. However, no such relationship was found between hypertension and treatment outcome ($p>0.05$).

In our study, we found that patients younger than 50 years had better rates of recovery in comparison to older patients. Similar findings have also been reported by Topuz et al.,^[21] who compared the treatment outcomes of two different groups (steroid+plasma expanders vs. steroid+plasma expanders+HBO therapy), and found better hearing outcomes particularly in patients younger than 50 years in the second group. In a recent guideline on SSNHL, it was also mentioned that younger patients (aged 50-60 years) responded better to HBO therapy than older patients.^[1]

Existence of vertigo and tinnitus symptoms was considered as a negative prognostic factor.^[22,23] In some studies, lower recovery rates varying from 14 to 40% have been reported in patients with vertiginous symptoms.^[19,23] We did not find any statistically significant relationship between vertigo symptoms and

the treatment outcomes ($p>0.05$). The majority of our patients presented with tinnitus (24 out of 27), and no statistically significant difference was found between the existence of tinnitus and the treatment outcomes. Similar results have also been reported in many studies ($p>0.05$).^[2,19,20]

Effects of audiogram curves on the treatment success are controversial. In some studies, it was reported that down-sloping audiogram curves were associated with bad treatment outcomes^[24,25] while in another study, no statistically significant relationships were found.^[2] In our study, we did not find any statistically significant effects of audiogram configuration on the salvage therapy outcome ($p>0.05$).

Early intervention is crucial in the treatment of SSNHL and early salvage interventions may be expected to give better results. For this purpose, we aimed to analyze the effect of timing of salvage therapy on the treatment outcome; however, no statistically significant differences were found between the early and late groups in terms of treatment outcomes.

We think that the main limitation of our study is our sample size, similar studies with larger group of patients are needed to justify our results.

In conclusion, HBO therapy may be beneficial in some patients not recovering from SSSL with systemic and IT treatments and used as a last remedy for these patients. A slight or partial recovery can be seen in these patients, while better results may be expected particularly in younger and non-diabetic patients. Further studies with larger groups of patients are needed to justify our results.

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