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The Role of Hyperbaric Oxygen Therapy in Sudden Sensorineural Hearing Loss in Children

Çocuklarda Ani İşitme Kaybında Hiperbarik Oksijen Tedavisinin Yeri

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ABSTRACT

Objective: Sudden Sensorineural Hearing Loss (SSNHL) is an otological emergency. Permanent SSNHL can seriously affect the social life, psychology, and language development of pediatric patients. There is no consensus the treatment of SSNHL. We compared the etiology, prognostic factors, and treatment results in pediatric patients who received hyperbaric oxygen therapy (HBOT) in addition to systemic steroid therapy with a diagnosis of SSNHL.

Material and Methods: The files of 15 children were received HBOT with the diagnosis of SSNHL, between the ages of 8-18 years, and followed-up at least three months were retrospectively analyzed.

Results: The ages of patients with SSNHL ranged from 8 to 18 years of age (mean 14.47±3.31 years). Seven (46.7%) patients had complete recovery, and two (13.3%) patients had partial recovery, two (13.3%) patients had slight recovery, four (26.7%) patients had no improvement. While pre-treatment PTAs of the patients were ranged between 28 to 109 dB HL (mean±sd; 57.3±26.2 dB HL), post-treatment PTAs were 6 to 88 dB HL (38±27.3 dB HL), (p=0.002). No significant difference was found between age, gender, number of HBOT sessions and response to treatment (p = 0.581, p = 0.904, p = 0.357, p = 0.184, respectively).

Conclusion: Hyperbaric oxygen therapy is a safe and well-tolerated treatment modality for pediatric SSNHL patients. To avoid ethical and legal problems, we think that pediatric patients with a diagnosis of SSNHL should be initiated with the consent of the patient's parents.

Key Words: Adolescent, Child, Hyperbaric oxygen therapy, Prognosis, Sudden Hearing Loss

ÖZ

Amaç: Ani Sensörinöral İşitme Kaybı (ASNIK) otolojik bir acil durumdur. Kalıcı ASNIK, çocuk hastaların sosyal yaşamını, psikolojisini ve dil gelişimini ciddi şekilde etkileyebilir. ASNIK tedavisi konusunda fikir birliği yoktur. ASNIK tanısı ile sistemik steroid tedavisine ek olarak hiperbarik oksijen tedavisi (HBOT) alan çocuk hastalarda etiyoloji, prognostik faktörler ve tedavi sonuçları karşılaştırıldı.

Gereç ve Yöntemler: ASNIK tanısı ile HBOT uygulanan 8-18 yaşları arasında en az üç ay takip edilen 15 çocuğun dosyaları geriye dönük olarak incelendi.

Bulgular: ASNIK'li hastaların yaşları 8 ile 18 yaş arasındaydı (ortalama 14.47±3.31 yıl). Yedi (% 46.7) hastada tam iyileşme, iki (%13.3) hastada kısmi iyileşme, iki (% 13.3) hastada hafif iyileşme, dört (% 26.7) hastada düzelme olmadı.

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Ethics Committee Approval / *Etik Kurul Onayı*: This study was conducted in accordance with the Helsinki Declaration Principles. The study, Health Sciences University Izmir Bozyaka Education and Research Hospital Clinical Research Ethics Committee approved (21.102020/08).

Contribution of the Authors / Yazarların katkısı*: *OZER EE: Constructing the hypothesis or idea of research and/or article, Organizing, supervising the course of progress and taking the responsibility of the research/study, Taking responsibility in patient follow-up, collection of relevant biological materials, data management and reporting, execution of the experiments, Taking responsibility in logical interpretation and conclusion of the results, Taking responsibility in necessary literature review for the study, Taking responsibility in the writing of the whole or important parts of the study, Reviewing the article before submission scientifically besides spelling and grammar. ***AYSEL A:*** Constructing the hypothesis or idea of research and/or article, Planning methodology to reach the Conclusions, Taking responsibility in patient follow-up, collection of relevant biological materials, data management and reporting, execution of the experiments, Taking responsibility in logical interpretation and conclusion of the results, Taking responsibility in necessary literature review for the study, Taking responsibility in the writing of the whole or important parts of the study, Reviewing the article before submission scientifically besides spelling and grammar.

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Hastaların tedavi öncesi Saf Ses Ortalamaları (SSO) 28 ile 109 dB HL (ortalama±ss; 57.3±26.2 dB HL) arasında değişirken, tedavi sonrası PTA'ları 6 ile 88 dB HL (38±27.3 dB HL), (p=0.002). Yaş, cinsiyet, HBOT seans sayısı ve tedaviye yanıt arasında anlamlı bir fark bulunmadı (sırasıyla p = 0.581, p = 0.904, p = 0.357, p = 0.184).

Sonuç: Hiperbarik oksijen tedavisi, pediatrik SSNHL hastaları için güvenli ve iyi tolere edilen bir tedavi yöntemidir. Etik ve yasal sorunlara yol açmamak için ASNIK tanısı alan çocuk hastaların ailelerinin onayı ile tedaviye başlanması gerektiğini düşünüyoruz.

Anahtar Sözcükler: Ergen, Çocuk, Hiperbarik oksijen tedavisi, Prognoz, Ani İşitme Kaybı

INTRODUCTION

Sudden sensorineural hearing loss (SSNHL) develops within three days in a person with previously normal hearing and occurs with a hearing loss of more than 30 decibels at least three consecutive frequencies on the audiogram. SSNHL is an otological emergency (1). Permanent SSNHL can seriously affect the social life, psychology, and language development of pediatric patients (1,2).

SSNHL is found in all age groups that most commonly between the ages of 30-60, but fewer cases have been reported in children and the elderly (3). Alexander and Harris reported the incidence as 11/100000 in children under 18 years of age and 27/100000 in patients over 65 years of age (4). Most of the cases are unilateral; less than 2% of patients have bilateral hearing loss. However, the fact that the rate of spontaneous recovery of the disease is quite high and that most of these patients are not recorded because they do not consult a physician, it is thought that the real incidence is much higher than these reports (4).

Considering the gender distribution in SSNHL patients that observed no significant difference between the female and male rats (4).

The degree of hearing loss can range from mild to total hearing loss. Tinnitus, vertigo, and dizziness may accompany hearing loss (4).

Most of the cases of SSNHL are idiopathic. In the etiology of SSNHL that multiple factors such as infectious, vascular, autoimmune systemic diseases, neoplasia, trauma, ototoxic drugs (4).

There is no consensus the treatment of SSNHL, since there may be more than one factor in the etiology of SSNHL (4,5).

In clinical practice, many centers have developed combined treatment protocols containing multiple agents for the possible etiology of SSNHL. The main treatment methods are combined therapies including corticosteroids, hyperbaric oxygen therapy, vasodilators, antivirals, and vitamins. Hyperbaric oxygen therapy aims to increase oxygenation in the tissue and reduce inflammation and edema (6).

According to The Committee of the Undersea and Hyperbaric Medical Society, one of the indications for hyperbaric oxygen therapy (HBOT) is SSNHL (6). HBOT is used as a primary or recovery therapy as a combined method with intratympanic or systemic steroids (6,7). The use of HBOT in SSNHL treatment is based on an increase in perilymph oxygenation (8). HBOT reduces cochlear hypoxia, edema, and damage (6-8).

HBOT has been used frequently in the treatment of SSNHL in the last 20 years (6,7). HBOT must be explained to patients as a treatment option. Some authors recommend starting treatment within 48 hours or at the latest within 2 weeks (6-8). Some authors have suggested that HBOT can be combined with steroids, especially in patients with hearing loss greater than 70 dB (9). A clear consensus could not be reached on whether HBOT should be used alone or as an adjunct or recovery therapy for the SSNHL (9,10). However, considering its mechanism of action, HBOT should be used in combination with other treatments at an early stage (11).

HBOT is a medical treatment based on breathing 100% oxygen continuously or intermittently under pressure higher than 1 atmosphere absolute (1 ATA, 1 Bar, 760 mmHg) in the pressure chamber. Treatments usually take 90 to 120 minutes and depending on the indication, one or more sessions per day can be applied (11).

The most common complication of HBOT is barotrauma in the ear, sinus, and teeth due to pressure changes. Middle ear barotraumas are the most common among barotraumas and can also be prevented by patient education and slow compression-decompression (11,12). Ear equalization training is given to patients before treatment, especially with the Valsalva maneuver (11,12). You will appreciate that it is difficult in terms of treatment compliance to provide these training in children and for children to apply these maneuvers (11,12). Myringotomy may also be an option if there is an unsuccessful ear equalization (11,12). Due to the nature of the treatment, claustrophobia is another possibility. Parents can also accompany the treatment for support purposes, especially in young children (11,12). Of course, detailed anamnesis for parents should be taken especially in terms of pneumothorax risk. Lung barotrauma is another rare but serious complication (11,12). During decompression, alveolar rupture may occur in lesions that cause air trapping in the lung (cyst, cavern, etc.), bronchial obstruction (11,12). It can cause pneumothorax, pneumomediastinum, subcutaneous emphysema, and gas embolism (11,12). Therefore, a detailed history and consent should be taken before treatment from the patient's parents (11,12). The side effects mentioned are extremely rare. This makes the treatment selectable (11,12).

The literature on the use of hyperbaric oxygen therapy in hearing loss in the pediatric population is limited. In this study, we compared the etiology, prognostic factors, and treatment results in pediatric patients who received HBOT in addition to systemic steroid therapy with a diagnosis of SSNHL. We aimed to contribute to the literature with our cases.

MATERIALS and METHODS

A retrospective chart review was performed to identify patients who were admitted to our center with the diagnosis of SSNHL and received HBOT between January 2016 and October 2020. The files of 15 children, between the ages of 8-18 years and followed-up at least three months were retrospectively analyzed. The study, Health Sciences University Izmir Bozyaka Education and Research Hospital Clinical Research Ethics Committee approved (21.102020/08). Written informed consent was obtained from the patients participating in the study .

While patients with pure tone audiometry before and 5. Day, 14. day and at least 3 months after treatment were included, patients with acute-chronic otitis media, middle ear, and retrocochlear pathology, autoimmune inner ear disease, Meniere's disease, syndromic and genetic hearing loss, patients who underwent surgery were excluded in the study.

In pure tone audiometry, the average pure tone thresholds of 500 Hz, 1000 Hz, 2000 Hz , and 4000 Hz were accepted as pure tone averages (PTA). Following the American Speech and Hearing Association guidelines, the severity of hearing loss was based on the PTA as follows;

- 25-40 dB HL mild,
- 41-55 dB HL moderate,
- 56-70 dB HL moderate-severe,
- 71-90 dB HL severe
- >90 dB HL profound.

Patients' recovery status was determined according to Siegel's criteria (13) (Table I).

In pure tone audiometry, the average of 500, 1000, 2000, and 4000 Hz frequencies was calculated as the pure tone average (PTA).

Audiogram configurations were evaluated in three groups, ascending (hearing losses keeping 250-500 Hz), descending (hearing loss keeping 4000-8000 Hz), flat type (less than 20 dB difference between the best and worst hearing thresholds hearing losses) (14).

All patients were treated with systemic steroids. Oral methylprednisolone was administered at a dose of 1 mg/kg and tapered in 14 days. Patients who did not improve or had a PTA greater than 60 dB HL at the fifth-day control audiogram, were injected three doses (1 dose=0.5 ml=2mg) of intratympanic dexamethasone solution (Dekort, DEVA Corporation, Istanbul, Turkey) every other day if they tolerated the injection. Patients with a history of upper respiratory tract infection were tested for CMV, EBV, Mumps, Herpes viruses (HSV, VZV), and Influenza, and antiviral treatment was initiated in patients with positive viral serology.

All patients were administered 1 session 2.4 ATA a day for 120 minutes, for 4 weeks. (20 sessions in total) One HBOT session lasts 120 minutes. Patients breathe oxygen at 2.4 ATA for 90 minutes. There is a 5-minute air break between each oxygen period (30 minutes). Oxygen is inhaled through a mask in the pressure chamber.

Statistical Analysis

Descriptive statistics was calculated for all variables, an association between the groups were evaluated using the Chi-square test. The Independent Samples t-test was used to compare the means of two independent groups and the nonparametric Mann-Whitney U test was applied to investigate continuous variable prognostic factors. All statistical analyses were performed using SPSS version 22.0 (IBM SPSS Statistics, Chicago, IL, USA). A p-value less than 0.05 was considered statistically significant.

RESULTS

Fifteen children were treated with the diagnosis of SSNHL during the study period. All patients had idiopathic etiology. The ages of patients with SSNHL ranged from 8 to 18 years of age (mean 14.47 ± 3.31 years).

Nine (60%) of the patients were boys and 6 (40%) were girls. While the hearing loss was on the right side in 46.7% (n = 7) of the children, it was on the left side in 53.3% (n = 8) (Table II). Hearing loss was bilateral in none of the patients.

Nine patients had tinnitus accompanying hearing loss (Table II). The degrees of sensorineural hearing loss were; 26.7% (n=4) mild, 40% (n=6) moderate, 20% (n=3) severe, 13.3% (n=2) profound.

Table I: Siegel Criteria.

Complete recovery	Final hearing level was better than 25 dB HL
Partial recovery	More than 15 dB HL of gain, final hearing 25-45 dB HL
Slight improvement	More than 15 dB HL of gain, final hearing poorer than 45 dB HL
No improvement	Less than 15 dB HL of gain or final hearing poorer than 75 HL dB

dB : *Decibel,* ***HL :*** *Hearing Level*

Table II: The clinic, demographics and history of patients

Case No	Age	Gender	Side	Degree of Hearing Loss	Audiometric Type	Outcomes (Siegel)	Concurrent Symptom	Comorbidity	HBOT Sessions	Treatment
1	10	G	L	moderate	Descen.	no impr.	none	none	15	SS+ITS
2	11	B	R	mild	flatting	no impr.	none	none	18	SS
3	11	B	R	severe	flatting	no impr.	none	none	20	SS
4	12	B	L	moderate	Ascen.	complete	tinnitus	none	15	SS
5	14	G	L	moderate	Descen.	complete	tinnitus	none	15	SS
6	15	B	L	moderate	flatting	complete	none	ADHD	10	SS+ITS
7	15	G	R	mild	Descen.	partial	tinnitus	none	20	SS
8	16	B	L	severe	Descen.	complete	none	none	13	SS
9	16	B	R	profound	flatting	slight	none	none	25	SS
10	17	G	R	mild	Descen.	complete	tinnitus	Type 1 DM	10	SS
11	18	B	R	moderate	flatting	partial	none	none	7	SS+ITS
12	18	G	L	mild	Descen.	complete	none	none	40	SS
13	18	B	R	moderate	Descen.	complete	tinnitus	none	10	SS
14	18	G	L	severe	Descend.	slight	none	none	20	SS
15	8	B	L	profound	flatting	no impr.	tinnitus	none	15	SS+ITS

***B:** Boy, **G:** Girl, **R:** Right, **L:** Left, **HBOT:** Hiperbaric Oxygen Therapy, **ADHD:** attention deficit and hyperactivity disorder, **SS:** Systemic Steroid, **ITS:** Intratympanic Steroid.*

Eleven patients received systemic steroids+HBOT, four patients received systemic steroids + intratympanic steroids+HBOT. There was no significant difference in improvement between the two groups (p = .40).

Of the nine patients with tinnitus, 2 of the patients had mild hearing loss, 2 had moderate hearing loss, one had mild-moderate, 3 had severe hearing loss, and 1 had profound hearing loss. After HBOT, in two patients with mild hearing loss, 1 patient was observed complete recovery, while 1 patient was observed no improvement. In two patients with moderate hearing loss, 1 patient was observed complete recovery, while 1 patient was observed no improvement. Partial recovery was seen in one patient with moderate hearing loss. In three patients with severe hearing loss, 1 patient was observed complete recovery, 1 patient had slight improvement, and 1 patient had no improvement. A slight improvement was observed in one patient with profound hearing loss (Table II).

6 patients did not have any symptoms. After HBOT, of these patients, 2 patients with mild hearing loss had a full recovery and 1 patient had partial recovery. In 3 patients with moderate hearing loss, three patients were observed complete recovery. In 1 patient with profound hearing loss, no improvement was

Tablo III: Clinical results of Cases.

	Mean±SD (Minimum-Maximum)
Age (years)	14.47±3.31 (8-18)
Initial treatment time (day)	5.73±6.62 (1-27)
Follow-up (month)	26.7±9.7 (7-39)
PTApre (dB HL)	57.3±26.2 (28-109)
PTApost (dB HL)	38 27.3 (6-88)

SD: *Standart Deviation,* ***dB:*** *decibel,* ***HL:*** *Hearing Level,* ***PTA:*** *Pure Tone Averages.*

observed (Table II). It was found that the presence of tinnitus and no additional symptoms did not significantly different treatment outcomes (p = .449).

Seven (46.7%) patients had complete recovery, two (13.3%) patients had partial recovery, two (13.3%) patients had a slight recovery, four (26.7%) patients had no improvement (Table II).

While pre-treatment PTAs of the patients were ranged between 28 to 109 dB HL (mean±sd; 57.3±26.2 dB HL), post-treatment PTAs were 6 to 88 dB HL (38±27.3 dB HL), (p=.002). According to the audiogram configurations, one patient had ascending type, 8 patients had a descending type, 6 patients had flatting type (Table II).

Five of the 8 patients with descending type audiogram, 5 patients had complete recovery, one patient had partial recovery, one patient had slight improvement, and one patient had no improvement. Of the six patients with a flatting type audiogram, one patient had complete, one patient had partial, one patient had slight improvement, while three patients had no improvement. One patient with ascending type audiogram had complete recovery (Table II). There was no significant difference between audiogram type and treatment outcomes (p = .509).

Ten of the 15 patients applied to us within the first five days after the onset of hearing loss. After HBOT, 4 patients had complete recovery, 2 patients had partial recovery, 1 patient had slight improvement, and 3 patients had no improvement (Table II).

The mean follow-up period ranged from 7 to 39 months (mean 26.7±9.7).

The time passed from hearing loss and initiation of the treatment was 1-27 days (mean 5.73±6.62) (Table III). The number of HBOT sessions the patients received was 16.87 ± 8.02 (7-40), (Table III).

It was observed that five patients who started treatment between the 6th and 27th days, 3 patients had complete recovery, one patient had slight improvement, and one patient had no improvement (Table II).

No significant difference was found between age, gender, number of HBOT sessions and response to treatment (p = .581, p = .904, p = .357, p = .184, respectively).

Complications such as rupture of the eardrum, serous otitis media, claustrophobia, and oxygen toxicity did not occur in any of the patients. Patients' demographics and history are summarized in Table II.

DISCUSSION

Since multiple mechanisms are blamed in the etiology of SSNHL, multiple treatment protocols are often preferred. Steroids, hyperbaric oxygen therapy, antiviral drugs, vitamins, anticoagulants, vasodilators are the most preferred treatment options used in different combinations (15). Hyperbaric oxygen therapy (HBOT) was first used for SSNHL in the late 1970s (16).

The cochlea is an organ that requires high oxygen but has a relatively limited vascular supply. With HBOT, 100% oxygen is given at high pressure to increase the diffusion of oxygen to the inner ear. Many studies have shown that early treatment with HBOT is more beneficial than late treatment (17-19). There is no clear information in the literature regarding the HBOT regimen.

According to the guidelines of the American Otorhinolaryngology Academy- Head and Neck Surgery Foundation published in 2019, HBOT and steroid combination is accepted as the initial treatment in the first 2 weeks, and HBOT + steroid combination, which is started within 1 month, is recommended as a rescue therapy (18,19).

In the literature, absolute atmospheric pressure (from 1.5-2.8 ATA) varied between the duration of the treatment session (30-120 minutes), and the amount amount amount amount number of sessions given (10-25 sessions) 18-20).

HBOT has been used either alone or in addition to other medical treatments in the treatment of SSNHL (19,20).

In some studies, they found that starting HBOT at the earliest time (up to 2 weeks at the latest) was beneficial, especially in severe hearing loss (over 70 dB) (20). In this study, HBOT+oral steroid was started in all our patients, and oral + intratympanic steroid+HBOT was started in 4 patients. HBOT was started in the first 2 weeks in 14 of 15 patients.

Early initiation of treatment, absence of vestibular symptoms, presence of tinnitus, ascending type hearing loss in the audiogram, and unilateral hearing loss are considered as good prognostic factors (18-20). Late initiation of treatment, descending type of hearing loss on the audiogram, presence of vestibular symptoms, bilateral hearing loss, total or total near-total hearing loss are considered as poor prognostic factors (18-20). In our study, improvement was found in 7 of 9 cases with tinnitus. These results supported the positive effect of tinnitus on prognosis.

One of the most important factors affecting the prognosis of the disease is the degree of initial hearing loss. Initially, the

severity of the hearing loss is a negative prognostic factor, and the deeper it is, the less expected recovery of hearing (20). In our study, one of the five patients with severe and profound hearing loss had complete recovery, two patients had slight improvement, and two patients had no improvement. Six of the 10 patients with mild, mild-moderate, and moderate hearing loss had complete recovery, two had partial recovery, and two had no improvement.

Another important prognostic factor determining the response in treatment is the time elapsed between the onset of hearing loss and the initiation of treatment, the earlier the treatment is initiated, the better the response will be obtained. It is thought that after 30 days, the active process resolves and the damage becomes permanent (20). Although there is no common consensus about the time to start treatment, the opinions are that it should be started as soon as possible. 14 of our patients were started treatment within the first 2 weeks.

According to audiogram types, some articles have shown that ascending type audiograms have a better prognosis compared to descending type audiograms (19-21). In our study, one patient had ascending type audiogram that was observed complete recovery. We found improvement in 7 of 8 patients with a descending type audiogram.

Overall (complete + partial+ slight) recovery rates in pediatric SSNHL were reported between 55.20% and 70.67% in the literatüre (20-22). In our study, overall recovery rates were reported 73.33% (n=11/15). The limitations of this study include its retrospective nature and the limited number of patients in the pediatric population. Another limiting factor is that we applied HBOT to all patients. The presence of a hyperbaric center in our hospital may cause this.

Although the early application of HBOT is recommended, it may not be possible in practice. Especially in Turkey, begun to spread HBOT centers as well as public and private centers in recent years it is not available in all provinces. Current HBOT centers can be found at www.sualti.org. It is cost-effective that is another question that comes to mind. There is a significant percentage of patients known to recover spontaneously (23).

However, it is not known which patient will be left to recover spontaneously. Failure to apply an available treatment can also be an ethical crime. HBOT costs are very low in Turkey compared to other countries in the World (24). Its addition to routine steroid treatment can be said to be cost-effective.

CONCLUSIONS

Hyperbaric oxygen therapy is a safe and well-tolerated treatment modality for pediatric SSNHL patients. To avoid ethical and legal problems, we think that pediatric patients with a diagnosis of SSNHL should be initiated with the consent of the patient's parents.

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