



USE OF HYPERBARIC OXYGEN THERAPY (HBOT) AS A NOVEL TECHNIQUE IN MANAGEMENT OF SENSORINEURAL HEARING LOSS.

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ABSTRACT

Introduction: Sensory Neural hearing loss (SNHL) is a condition when patient's capability of hearing sound is reduced or absent due to neurological causes, or cochlear causes. It can be mild, moderate or severe depending on the capability of hearing. Treatment modalities are very limited. Use of steroids and hearing aids are among the few options patients have. However effective modality is yet to be discovered. **Aim-** To study the role of Hyperbaric Oxygen Therapy (HBOT) as a treatment modality for SNHL. **Methodology:** The study prospective study, done on 22 patients of SNHL, who had failed response from other treatment modalities. Patients who were diagnosed having SNHL, by clinical as well as audiometric examination, were recruited in the study. All patients were already undergone conservative treatment and still had unresponsive hearing loss, were included in the study. Patients were evaluated and subjected to HBOT sessions on daily basis. After completion of HBOT, pre and post therapy parameters were compared to find out the effectiveness of HBOT. Statistical analysis was done with the help of SPSS 28.0 version. The dichotomous variables were presented in number/frequency, were analysed using Chi-square test. p-value of <0.05 was considered as significant and p value of 0.001 was regarded as highly significant. **Result:** Clinical improvement as well as audiometric improvement was seen in all patients after completion of the therapy. **Conclusion:** HBOT is a non-invasive and effective modality in the treatment of SNHL.

KEYWORDS : Hyperbaric oxygen therapy, hearing loss, sensory neural hearing loss, unresponsive hearing loss.

Introduction

Hearing loss if one of the commonest complaints with which patient comes in ENT surgeon. There are several causes of hearing loss, which are categorised in two types. Conductive Hearing Loss and Sensory Neural Hearing Loss (SNHL). Conductive hearing loss occur due to impairment of conduction of sound via external ear or internal ear or both. Whereas SNHL occur due to impairment within cochlea, auditory nerve or central nervous system. SNHL remains the most common cause of hearing loss. [1]

Burden of the disease- world-wide prevalence of the disease was noted as 17.2% in 2008, which increase more than 18.7% after 2017. WHO declared hearing loss as third most common cause of years lost due to disability. Almost one third population of world age more than 65 years, suffer from disabling hearing loss. The national sample survey for Hearing loss declared it as second most common cause of disability. The Indian census and national sample survey data showed hearing loss as most common form of disability in Indian population. [2]

Various Causes of SNHL- Hereditary, Loud noise, more than 80-90 Db, Meniere's disease, Presbycusis, Head injury, Systemic conditions like meningitis, DM, Vestibular schwannoma Ototoxic drugs like Aminoglycosides, loop diuretics, chemotherapeutic drugs, Barotrauma, Aging and Autoimmune conditions, Syndromic, congenital hearing loss, and idiopathic hearing loss. Noise acts as a strong agent for hearing loss. It is believed that most common cause of SNHL in younger age group is noise induced hearing loss, whereas age related degenerative conditions are commonest cause of SNHL in old age. [3]

Clinical examination and diagnosis of hearing loss includes

Otoscope examination- This a helpful clinical examination of the external canal and tympanic membrane. Pathological conditions of the external ear, tympanic membrane, and middle ear can be evaluated and ruled out by otoscopic examination.

Clinical testing- weber test and Rinne test are two most commonly done and most useful tests to distinguish between conductive from

sensorineural loss. These tests are done with the help of a low frequency tuning fork, usually 512 Hz, and contrast measures of air and bone conducted sound transmission.

Other useful tests includes oto-acoustic emissions, acoustic stapedial reflexes, speech audiometry and evoked response audiometry etc. for detailed evaluation of clinical examination.

Tympanometry- this test is useful to assess functions of middle ear and mobility of tympanic membrane. This test is useful in identification of conductive hearing loss due to diseases of middle ear and ear drum.

Audiometry - PTA (pure Tone Audiometry) is the commonest test for assessment of hearing. It detects the hearing threshold at frequencies 250- 8000 HZ. PTA is important tool for differentiation between SNHL, conductive hearing loss and mixed types of hearing loss. It can also be used to categorise the hearing loss in to mild, moderate, severe. Hence it is not only useful in diagnosis but also useful in guiding the treatment and prognosis.

Magnetic resonance imaging-MRI is an important tool for identification of inner ear pathology, nerve pathology and various tumorous conditions leading to hearing loss. [4]

Treatment of hearing loss- Broadly treatment can be categorised in to three categories, Pharmacological, Surgical, and Newer modalities.

Traditional pharmacological treatment- which involves vitamins and antioxidants like high doses of vitamins A, C, and E, Magnesium, vasodilators, rheologic agents, corticosteroids, intra tympanic steroids injections, anti-inflammatory agents, betahistine, and Coenzyme Q10 are various drugs used in the treatment of SNHL. [5]

Surgical techniques include- cochlear implants, hearing aids etc however surgical techniques in SNHL are not commonly performed, due to cost and surgical complications.

Newer modalities- such as Stem Cell therapy and Gene Therapy and hyperbaric oxygen therapy. Although the application of stem cell in hearing loss is may provide a promising result but validation of this

procedure, its implantation in to ear, functional restoration, immune rejection and tumorigenicity is not well understood till date. [6]

Although there are multiple options for treatment of SNHL, but none of the modality has shown the promising results. Patients have to undergo multiple visits to hospital , prolonged medications and even surgical interventions but standard treatment option is lacking till date. However few studies have shown effectiveness of Hyper Baric Oxygen Therapy (HBOT) in the treatment of SNHL.

As the name suggests, hyperbaric oxygen contains oxygen at higher pressure, HBOT provides 100% oxygen at more than atmospheric pressure, i.e 1 ATA. Although HBOT was discovered and used very early, in 1620, when Drebbel designed a diving bell for HBOT. Later Henshaw designed another chamber called domicilium. In 1928 dr, Orville Cunningham designed another multi chambered, multistoried delivery system, which could deliver oxygen at 3 ATA. [7]

Rapid rise in the use of hyperbaric oxygen began in 1937, it was invented as an effective treatment modality for decompression sickness by Behnke and Shaw .

In the modern era there are numerous indications of HBOT, which are approved by Undersea and Hyperbaric Medicine Society (UHMS) British Hyperbaric Association.

Various indications of HBOT are Air embolism, CO poisoning, arterial insufficiencies, Crush injury, compartment syndrome, compromised skin grafts and flaps, necrotising fasciitis, burn injuries, radiation induced damage, chronic osteomyelitis, sensory neural hearing loss etc. [8,9,10]

Although HBOT is a relatively safe procedure but there are various contraindications of HBOT, which includes Untreated pneumothorax, Sinus infection, Upper respiratory infection, Pulmonary lesions on chest x-ray, High fever (greater than 39C), History of chest or ear surgery, Any convulsive disorder , Middle ear infection, Pregnancy, Acute Hypoglycemia etc.

Mechanism of action of HBOT in SNHL

HBOT increases the oxygen tension in perilymph space via labarinthine arteries, hence any arterial pathology like sclerosis, stenosis, obstruction, compression may alter its efficacy. However if HBOT is given along with other medications like thrombolytics, vasodilators, or antioxidants and steroids, its efficacy can be increased and hearing can be improved. [11,12]

HBOT has been used widely for various indications like nonhealing wounds, compromised grafts and flaps, radiation necrosis, burn etc. at various centres. As mentioned above SNHL, which is a cumbersome, and high burden disease, is also an indication for use of HBOT. The idea behind this article is to explore effectiveness of HBOT in treatment of SNHL.

SNHL can produce major psychological impact on the patient also effecting their personal, social and occupational life. Even some times the presence of tinnitus or giddiness is more cumbersome for the patient than the disease itself. Although till date only few treatment options are available for SNHL, but its prognosis of depends on various factors like time on onset, age of the patient, presence or absence of vertigo, degree of hearing loss, presence of metabolic disorders, presence of systemic vascular diseases etc. [13]

On search of literature we could find only few studies ascertaining the effectiveness of HBOT as an effective modality in treatment of SNHL. Many studies showed inconclusive and contradictory results, and also standard protocol of HBOT administration was lacking. The aim of our study is to identify whether HBOT can be considered as an effective modality in the treatment of SNHL or not. Also to define a standard protocol for HBOT administration.

Objectives

1. To study the effectiveness of HBOT as an effective modality in the treatment of SNHL.
2. To make a standard protocol of HBOT for treatment of SNHL.

Inclusion criteria

Age between 16 to 70 years

Patients in whom other causes of neural degeneration were ruled out
Patients who consented for the study

Exclusion criteria

Patients with contraindications of HBOT
Psychologically unstable patients

Parameters assessed

Clinical assessment- whispering, subjective assessment of hearing.
Audiometric assessment- Pure Tone Audiometry

All parameters will be assessed before starting the treatment, after completion of first week, second week, third week and fourth week. Final comparison will be done among parameters of pre- therapy and post- therapy.

Material and Methods

The present study is Prospective Observational Study done in the Patients of SNHL undergoing treatment in otolaryngology department, and were referred to our department for hyperbaric oxygen therapy.

This study was conducted in the department of Plastic and reconstructive Surgery of our institute. This is a prospective study done during the period, January 2022 to June 2022. 20 patients of SNHL who visited in the departmental OPD and who were found to be fit for HBOT, were included in the study. Procedure was explained to the patient and attendants. Patients were thoroughly examined to rule out contraindications of HBOT other causes of hearing loss. Presence of any systemic diseases, degenerative diseases affecting hearing were also ruled out. Detailed psychiatric evaluation was done in all patients. Detailed ear, including tympanic membrane assessment was done. Fitness for HBOT was obtained in all patients. Informed consent was obtained from all patients for procedure, photography, as well as publication. Audiometry of bilateral ear was done in all patients for documentation as well as comparison before starting the procedure of HBOT. Patients were not getting any other medical treatment for hearing loss. Patients were given a trial session of pressure of 1.5 ATA for 15- 20 minutes and were observed for any discomfort. If they tolerated the trial session then, regular sessions were started from next day onwards. Pressure of HBOT chamber was increased gradually from 1.5 ATA to maximum of 2.5 ATA, depending on their tolerance. Duration of session was also increased gradually up to 60 minutes. Patients were subjected to the treatment daily on OPD basis (Figure 1).



Figure 1: Patient entering in HBOT chamber

HBOT was administered as shown in following table (table 1), according to standard protocol of our hospital.

Table 1: Standard operating Protocol for HBOT

Day	Chamber pressure (ATA)	Duration of exposure	Post-session observation
1 (Trial session)	1.5 ATA	15-20 min.	15 min.
2	1.7 ATA	40 min	15 min.
3	1.8 ATA	40 min	15 min.
4	1.9ATA	40 min	15 min.
5	2.0 ATA	40min	15 min.
6	2.1 ATA	50 min	15 min.
7	2.2 ATA	60 min	15 min.
8	2.3 ATA	60 min	15 min.
9	2.4 ATA	60 min	15 min.
10	2.5 ATA	60 min	15 min.
11th day till completion	2.5 ATA	60 min	15 min.

Clinical assessment was done weekly during the session. Therapy was stopped after 4 weeks, if significant improvement was seen, otherwise it was continued for another 2 weeks. Un-responsiveness to therapy was declared only after completion of 6 weeks of therapy. Bilateral ear audiometry was done after completion of therapy. And comparison of pre and post therapy audiometry was done in all patients.

Statistical Analysis

Statistical analysis was done with the help of SPSS software. SPSS Inc., Chicago, IL, USA for Windows program, 28.0 version was used for analysis. When required, evaluation of continuous variables was done by mean with standard deviation, or range value. The dichotomous variables were presented in number/frequency, which were analysed using Chi-square test. p-value of <0.05 was considered as significant and p value of 0.001 was regarded as highly significant. Demographic profile and clinical outcomes are shown in table 2. (Table2)

Table 2: Demographic profile, Clinical characteristics and outcome of the patients enrolled in the study (n=22)

characteristics	number	P value
Age	Average-49.17 Y	-
Sex	M: F ratio 15:7	-
Duration of SNHL	Acute-13 Chronic-9	X=8.347, p=0.7696
Type of SNHL	Mild- 7 Moderate-9 Severe-6	X= 0.08577, p=0.9223
Etiology	Idiopathic-21 Infective-1	X=24.15, p<0.0001*
Average number of HBOT cycle	43+/-7	-
Average duration of HBOT cycle	39.53 _+8.84 minutes	X=2.75, p=0.0366
Hearing improvement		
4th weeks	4	X=0.09457, p=0.6578
8th week	15	P=0.003*
10th week	22	p>0.05
No response	00	P=0.0001*
Worsening of disease	00	P=0.0001*
Complications of HBOT	No	-

Result

1. Age – Age ranged between 16 to 70 years. With the mean age of 49.17 years with 11.83 SD. Patients were also grouped in age ranges as less than 20 years (1 patient), 21 to 40 years (13 patients), 41 to 60 (29 patients) years and more than 60 years (10 patients). Age group of 40 to 60 years was found to be more commonly affected.

2. Sex- Male were affected more as compared to females. Out of total 22 patients 15 were male, whereas 7 were female.

3. Duration of onset of SNHL- In our study most of the patients had acute onset of hearing loss. Total 13 patients had acute onset of hearing loss whereas 9 patients had chronic hearing loss.

4. Severity of hearing loss- All patients were categorized in to mild, moderate and severe hearing loss, based on their pre-treatment pure tone audiometry. 7 patients had mild hearing loss, 9 patients had moderate hearing loss, and 6 patients had severe hearing loss.

5. Possible contributing factors – Most of the patients (21 out of 22) had unknown cause of hearing loss. One patient had history previous recurrent ear infection leading to hearing loss.

6. Number of HBOT cycles- Number of HBOT cycles ranged between 21 to 70, with average of 43 _+ 7.

7. Duration of cycles- HBOT was administered for 15 minutes during trial session and after that it was gradually increased up to 60 minutes. Average duration of HBOT therapy was 39.53 _+8.84 minutes in each session.

8. Improvement in hearing – clinical assessment of hearing was done

after 4 weeks and 10 weeks. 4 patients showed improvement in hearing after 4 week, 15 showed improvement after completion of 8 weeks, however all 22 patients were improved after completion of 10 weeks

9. Pressure of HBOT chamber - Pressure range was kept between 1.5 ATA to 2.5 ATA. HBOT was started and trial session was given at 1.5 ATA pressure, which was later gradually increased up to 2.5 ATA. None of the patients were subjected to pressure higher than 2.5 ATA.

10. Complications of HBOT- None of the patients developed major complications, however mild ear pain was observed in 6 patients, which was relieved without interruption of HBOT. None of the patients developed middle ear complications, Barotrauma or tympanic membrane perforation.

11. Worsening of disease- None of the patients showed worsening or progression of disease during hyper baric oxygen therapy.

12. Unresponsive to HBOT- All patients showed positive response after receiving HBOT, None of the Patients showed unresponsiveness to HBOT.

Discussion and conclusion

Sensory neural hearing loss (SNHL) is often known as deafness of sudden onset. Patients complains of unexplained and sudden onset of hearing loss in one or both ears. Unilateral ear hearing loss are relatively diagnosed late, as compared to bilateral ear hearing loss. Early diagnosis and treatment are key to successful outcomes.

Clinical presentation- most of the patients complaints of sudden loss or diminished hearing after waking up in the morning. However patients with unilateral hearing loss notice their disability while using phones, or when they experience difficulty of hearing of normal conversations. Some times patients may complaint of other symptoms like heaviness in ear, ringing sensation in ear, dizziness, vertigo etc.

Aetiology-

Most common cause of SNHL is idiopathic. There are only few cases (10-15%) in which cause can be identified. Herpes virus infections, 8th cranial nerve injury, vascular ischaemia of inner ear, Perilymph fistula, systemic lupus erythematosus, granulomatosis, autoimmune etc are various conditions associated with SNHL. In our study also most of the patients had unknown cause of hearing loss.

Pathophysiology of SNHL- SNHL is a condition which occurs due to abnormality of inner ear. Various phenomenon includes damage to vestibulocochlear nerve, damage to central system in brain, or damage to hair cells within the inner ear. The sound is transmitted to inner ear by interface between stapes and oval window. When sound reaches to cochlea it undergoes first amplification with the help of outer hair cells. Following which sound reaches to inner hair cells by electrochemical transduction. Acoustic signal is received by cochlea generating a waveform, which traverses the basilar membrane of the cochlea and causes stimulation of outer hair cells, which modifies the signal. Different parts of basilar membrane act differently various frequencies. Basal part of the basilar membrane reacts to the higher frequency sounds, whereas apical part of basilar membrane reacts to the relatively lower frequencies of sound. Inner hair cells converts the energy of travelling wave in to an electric potential which is transmitted via auditory nerve. [14,15]

various mechanisms which can cause SNHL are as follows

Noise trauma:

exposure to very high volume sound causes vibrational shift between tectorial and basilar membrane, which causes damage to stereocilia of outer hair cells. Sound more than 70 dB are considered as risky for development of hearing loss, sound of 125 dB can cause pain and the sound more than 125 dB can cause permanent ear damage. Sound of normal conversation ranges between 60-65 dB, sound of street noise is 70 dB, sound of dance floors can go up to 104 dB, sound close by thunder is 120 dB, sound of gunshot from hand held gun is 150-160 dB.

Drug induced:

various ototoxic drugs such as aminoglycosides and gentamycin acts as potassium channel blockers which stops the hair cells from depolarising. Change in ionic concentration also causes perilymph ionic concentration which affect its function.

Structural abnormalities of cochlea: trauma or congenital conditions.

Vascular causes: interruption of vascular supply of cochlea can cause severe damage, leading to nonfunction of cochlea. Vascular causes include trauma, tumours, systemic vascular events etc.

Metabolic causes: diabetes mellitus, acid base imbalance leading to ionic changes and endolymph disfunction can lead to cochlear disfunction.

Degenerative causes: They predominantly occur in age related hearing loss. Degenerative changes in organ of corti, stria vascularis, or afferent neurons might causes various degrees of hearing loss. [16,17,18]

Syndromic causes: Waardenburg syndrome, Usher syndrome, Pendred syndrome, Jervell and Lange-Nielsen syndrome, Alport syndrome etc are various syndromes associated with SNHL. [19,20] Although there are various methods of treatment of SNHL like medical, lifestyle change and surgical techniques. Newer techniques also have been introduced like gene therapy, stem therapy and hyperbaric oxygen therapy. Still cure of SNHL is not achieved by any technique satisfactorily. None of the techniques have shown effective and consistent results. Hence combination therapy is still considered as best therapy for SNHL. However few studies have shown promising results of use of HBOT as one of the treatment modality in SNHL.

HBOT is a technique where patient is exposed to oxygen at high pressure inside a closed chamber. The pressure is kept above atmospheric pressure i.e. 1 ATA. The pressure ranges between 1.5 to 3 ATA. Duration may be variable, depending on the disease, response and tolerance to the therapy. HBOT can be given maximum up to 60-90 minutes in a single session. [21]

HBOT functions primarily by causing hyperoxygenation and decreasing the bubble size. According to Henry's law "the amount of dissolved gas in a liquid is directly proportional to its partial pressure above the liquid" if the pressure is increased above atmospheric pressure the dissolved oxygen in the blood is increased and hence the tissue oxygenation is increased. Another effect of exposure to HBOT is decrease in bubble size. According to Boyle's law volume of gas or bubble size is inversely proportional to its pressure. Hence it is useful in treatment of decompression sickness, embolic phenomenon etc. HBOT has various secondary mechanisms of action, which include angiogenesis, fibroblast proliferation, vasoconstriction, leukocyte oxidative killing, toxin inhibition and antibiotic synergy. [22]

Study done by et al, which is a case report of a patient of SNHL with hypertension. Patient did not show any improvement with medical management, and he was subjected to hyper baric oxygen therapy, which was found to be effective. [23]

Bayoumy et. Al. reported HBOT as a effective modality in combination of corticosteroid as compared to corticosteroid alone. Similarly Chi et.al also compared outcomes of result of SNHL when treated by traditional therapy versus combination therapy. [24,25]

Almosnino et al. , compared treatment of SNHL with intratympanic or oral corticosteroids (control) compared treatments with additional HBOT. They observed hearing gains of 17.9 dB in the HBOT group, and 15.0 dB in the control group. They concluded that HBOT did not show a beneficial effect over therapy with corticosteroids. [26].

Cho et al. conducted a study comparing patients of SNHL treated with intratympanic corticosteroid versus intratympanic corticosteroid plus HBOT. They also found improved outcomes in HBOT treated groups. [27].

Khater et al. compared SNHL treated with combination medical therapy of systemic corticosteroids, intratympanic corticosteroids and antiviral therapy. They compared the combination medical therapy with combination ,medical therapy along with HBOT. The HBOT group showed better results. [28].

Hosokawa et al. conducted a study and compared three groups. Group 1 included HBOT and systemic corticosteroids, group 2 included intratympanic corticosteroids and systemic corticosteroids, and group

3 included systemic corticosteroids alone. They concluded that recovery rate was better in HBOT group as compared to other two groups. [29].

Study done by Cvorovic et.al. showed unfavourable result with the use of HBOT. They compared two groups, intratympanic corticosteroid with HBOT. They found that results with corticosteroid is better than HBOT group. Several studies have shown that HBOT is effective and supportive modality in the treatment of SNHL. Our study also showed improved outcomes when SNHL was treated with HBOT along with other drugs. Table 2 shows case details and outcomes of our study. [30] Various studies have compared the age groups and found that recovery from SNHL was better and more in younger population as compared to older population. In our study also younger patients were benefited more as compared to older population. [31,32,33]

However on the other hand the study done by Cekin et al. did not showed any significant difference in improvement in SNHL, when compared the younger population with older population. [34]

Conclusion

HBOT is an effective, relatively safe and non-invasive modality for treatment of sensory neural hearing loss. However a comparative study with larger sample size would be more effective to draw the conclusion.

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