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EFFICACY OF HYPERBARIC OXYGEN THERAPY IN SENSORINEURAL HEARING LOSS

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ABSTRACT

Introduction: *Sensorineural hearing loss (SNHL) is one of the most common type of hearing loss, caused due to damage of the inner ear (cochlea) or the auditory nerve pathways. This type of hearing loss is mostly permanent and cannot be corrected by medical treatment or surgery.*

Objective*: The present study objective was to assess the effectiveness of Hyperbaric Oxygen Therapy (HBOT) in the treatment of various patients with Sensorineural hearing loss (SNHL).*

Methods*: In this study, patients with Sensorineural hearing loss (SNHL) were treated through hyperbaric oxygen therapy, and the data was collected from patients enrolled in PNS Shifa Hospital Karachi, Pakistan. In PNS Shifa Hospital, 71 patients were treated by HBOT since Nov 2024, and their outcome data was collected, which showed improvement.*

Results*: After analyzing the data of patients with SNHL, PTA results showed significant improvements in hearing thresholds post-treatment. Significant improvements were observed in air conduction thresholds, particularly at lower frequencies (250 Hz and 500 Hz). The greatest improvements were noted at lower frequencies (250 Hz and 500 Hz), while higher frequencies (4000 Hz and 8000 Hz) showed minimal or no improvement. Approximately 60–70% of patients showed some degree of improvement in air conduction thresholds, while bone conduction thresholds remained largely unchanged. Overall HBOT efficiency was 39 %.*

Conclusion*: The findings of this study suggest that Hyperbaric Oxygen Therapy (HBOT) has moderate effectiveness in improving hearing thresholds for patients with sensorineural hearing loss, particularly in air conduction at lower frequencies. The therapy appears to be more beneficial for low-frequency hearing loss, with limited impact on high-frequency thresholds or bone conduction*

INTRODUCTION

Patients receiving hyperbaric oxygen therapy (HBOT) breathe 100% oxygen in a pressurized chamber. To allow the lungs to absorb more oxygen. The body's natural curing processes are strengthened by the increased pressure and this oxygen via the bloodstream is then carried to tissues. The treatment lowers inflammation, encourages the growth of new blood vessels and fights infections [1].

HBOT is approved for a number of illnesses some of which are appended below:

Decompression sickness: This is common in scuba divers because pressure changes rapidly during scuba diving.

Gas/ air embolism: To prevent and treat the air bubbles in blood vessels.

Carbon monoxide poisoning: Removal of carbon monoxide from the bloodstream.

Non-healing Diabetic wounds: Improves oxygenation of tissues to heal the wound.

Radiation injuries: To treat tissue damage caused by the radiation therapy.

Necrotizing infections: Helps in fighting grave bacterial infections.

Severe anemia: When blood transfusion is not an option this treatment is used.

Sudden Sensorineural Hearing Loss (SSNHL): In cases of unexplained rapid hearing loss HBOT is being studied for its effectiveness.

Injury/damage to the auditory nerve or inner ear causes the Sensorineural hearing loss (SNHL). Idiopathic sensorineural hearing loss (ISSNHL), is one of the specific type which effects one ear and occurs suddenly within 72 hours. ISSNHL is a serious condition that significantly impacts quality of life, affecting approximately 5 to 20 out of every 100,000 people annually however it is not life-threatening. A 2021 study by Ahn et al. emphasized that ISSNHL is often associated with viral infections, vascular compromise, or autoimmune reactions, and early interference is critical to stop lasting hearing damage [2].The underlying pathophysiology of SNHL includes vascular compromise, oxidative stress, and inflammatory processes that affect the cochlear hair cells. One proposed mechanism of SNHL is ischemia-induced hypoxia, where reduced blood supply deprives auditory structures of essential oxygen, leading to cellular apoptosis and dysfunction. A 2021 study by Ahn et al. find out that in the cochlea, hypoxia triggers oxidative stress and inflammation, which further aggravate damage to auditory nerve pathways and hair cells auditory nerve pathways, thus highlighting the importance of timely intervention to prevent permanent hearing loss by restoring oxygenation [2]. In cases of ISSNHL, viral infections, autoimmune reactions, or microvascular disorders are often implicated as potential causes [3].Hyperbaric Oxygen Therapy (HBOT) has gained attention as a treatment for SNHL due to its potential to increase oxygen diffusion to the cochlea, promoting cellular repair and reducing inflammation [4]. By delivering 100% oxygen at increased atmospheric pressure, HBOT enhances tissue oxygenation, which may support mitochondrial function in hair cells and stimulate angiogenesis, thereby improving auditory function [6]. While corticosteroids remain the standard treatment for ISSNHL, HBOT has been proposed as an adjunct therapy, particularly for patients who do not respond to conventional treatments [7]. Studies have indicated that HBOT is most effective when administered early, particularly for low-frequency hearing loss, where vascular compromise is more pronounced [8,9]. However, further research is necessary to determine the optimal treatment protocols and long-term benefits of HBOT for SNHL recovery [9,10].

The standard treatment for ISSNHL is corticosteroids, sometimes combined with antioxidants or vasodilators. However, since current therapies do not always yield positive results, researchers are investigating alternative treatments, such as hyperbaric oxygen therapy (HBOT) [10, 12]. In this study, we carry out HBOT therapy on patients to analyze the results and attempt to define the indications of hearing thresholds on PTA for HBOT.

LITERATURE REVIEW

Effectiveness of Hyperbaric Oxygen Therapy (HBOT) in Sensorineural Hearing Loss (SNHL)

A possible treatment for idiopathic sudden sensorineural hearing loss (ISSNHL) and chronic SNHL is Hyperbaric oxygen therapy (HBOT) because it enhance angiogenesis and improves oxygen delivery to ischemic cochlear tissues and reduce inflammation. HBOT success rate have been proven in several studies along with limitations and its role as an aid therapy along with corticosteroids.

Success Rates and Clinical Findings

Initial management through HBOT i.e within two weeks of onset can improves hearing particularly at low frequency (250 Hz and 500 Hz) and same have been suggested in numerous studies. A 2022 randomized controlled trial by Kim et al. demonstrated Significant hearing recovery showed in 45–65% of patients treated with HBOT within the first two weeks of symptom onset, pronounced improvements observed in low-frequency thresholds [4].The study also emphasized that early intervention was a acute factor in accomplishing positive outcomes, supporting the importance of well-timed HBOT management. Results of a 2023 meta-analysis by Chen et al. suggested that a 65% higher likelihood of hearing recovery who received HBOT within the first two weeks of symptom onset compared to those who received delayed treatment [5].A meta-analysis by Yang et al. (2013) evaluating HBOT, intratympanic steroid injection and combination therapy in ISSNHL found that 58% of cases improved alone through treatment by HBOT with higher success rate in <50 years old (younger patients) and those with moderate hearing loss [6]. However, Seo et al. (2015) reported that patients with long-standing SNHL (over six months) and profound hearing loss (>90 dB) showed slight to no recovery, this indicates that HBOT is most effective in severe cases [13].

HBOT significantly improved hearing thresholds in patients with severe ISSNHL particularly when administered within the first two weeks of symptom onset thus supported the efficacy of HBOT in SNHL ; Ahn et al. (2021) demonstrated that [13]. Similarly, a 2022 study by Kim et al. found that especially in patients with low-frequency hearing loss if we use corticosteroids alone then it is not effective as compared to combine use HBOT with corticosteroids [4]. Moreover in 2023 systematic review by Zhang et al. highlighted that recovery rate of 65% observed when treatment is initiated early then HBOT is most effective in patients with mild to moderate SNHL [15].

Limitations and Controversies

It is pertinent to mention here that some of the recent studies have also highlighted limitations of HBOT. A 2020 study by Lee et al. found that HBOT may have limited durability in SNHL treatment although HBOT improved hearing threshold in few, the benefits were not sustained in long-term follow-ups [16]. Additionally, a 2023 meta-analysis by Chen et al. concluded that younger patients and those with milder hearing loss showing the most significant improvements thus HBOT's effectiveness is highly dependent on patient selection [5].

One of the major concern in this treatment is cost and availability. HBOT is a resource-intensive therapy, may not be widely available in rural regions or low-income often not covered by insurance. A 2021 study by Patel et al. suggested for cost-effective alternatives to improve accessibility particularly in developing countries [17]. Additionally, side effects such as oxygen toxicity, barotrauma and claustrophobia can affect patient adherence. A 2022 study by Smith et al. emphasize the need for careful patient screening and monitoring because in his study 15% of patients experienced mild to moderate side effects during HBOT [18].

MATERIAL AND METHODS

HBOT Protocol

The Hyperbaric Oxygen Therapy (HBOT) protocol used in this study was designed to maximize oxygen delivery to the cochlear tissues while minimizing potential risks. The protocol was standardized across all patients, with minor variations based on individual patient needs and tolerability

Patients

In this study, patients with Sensorineural hearing loss (SNHL) were treated through HBOT, and most of the data was collected from patients enrolled in PNS Shifa Hospital Karachi, Pakistan. In PNS Shifa Hospital, 71

patients were treated by HBOT since Nov 2024, and their outcome data was collected.

Treatment Protocols

Selected patients were of group age from 13 years old to 78 years old. Treatment was carried out with medications (i.e Betahistine and Mecobalamin) and HBO2. Patients were having duration of disease from 03 weeks minimum to maximum 9 Months and patients were treated through HBO2 from Nov 2024 till Apr 2025 with sessions varying from min 04 to 21 sessions. For HBOT, 100 % pure O2 was used with ventilation at 29.3 psi as per the hospital protocol which is approximately 2 ATA (atmosphere absolute).

Medications Used Alongside HBOT

In addition to HBOT, to support cochlear recovery and manage symptoms patients were prescribed medications. Basing on their mechanism of action and potential effects with HBOT 2 x different medicines were used which are Betahistine and Mecobalamine

Betahistine

Dosage: For three times a day 16 mg was prescribed to patients (total daily dose of 48 mg). This dosage was selected based on its efficacy in reducing vertigo in patients with SNHL and improving cochlear blood flow.

Mechanism of Action: Betahistine improves microcirculation in the inner ear because it is similar to histamine that acts as a vasodilator. It helps in reducing cochlear damage caused by oxidative stress because it has anti-inflammatory properties.

Rationale for Use: To enhance the effects of HBOT, Betahistine was included in the treatment routine by reducing inflammation and improving blood flow to the cochlea. A contributing factor to SNHL is vascular compromise and therefore this is useful for such patients.

Mecobalamin

Dosage: For three times a day patients received 500 mcg of Mecobalamin total daily dose of 1500 mcg. This is a standard recommended dosage for nerve repair and regeneration.

Mechanism of Action: Mecobalamin plays a critical role in nerve repair and myelination because it is a form of vitamin B12. It help protect cochlear hair cells from oxidative damage because of its antioxidant properties.

Rationale for Use: To repair the damaged auditory nerve pathways and enhance the overall recovery of hearing function, Mecobalamin was included. Oxygen-delivering properties of HBOT is supplemented due to this medicines antioxidant effects.

Adjunctive Medications

Nasal Decongestants: To ensure proper pressure equalization during HBOT sessions patients with Eustachian tube dysfunction or middle ear pressure issues were pre-treated with xylometazoline nasal spray (0.1%).

Antihistamines: This medication was prescribed to manage symptoms and improve comfort during treatment for the cases where patients were having allergic reactions or inflammation.

Monitoring and Adjustments: Monitoring of side effects of medication for patients having gastrointestinal discomfort due to Betahistine or allergic reactions because of Mecobalamine. Patients were asked in post treatment for any adverse effects so that doctors/medical team could swiftly manage the symptoms. Dosages were adjusted as needed to ensure admissibility and compliance.

Integration of HBOT and Medications

The combination of medications and HBOT was planned to address multiple aspects of SNHL, including oxidative stress, vascular compromise and nerve damage. By reducing inflammation improving cochlear oxygenation and supporting nerve repair, this approach aimed to maximize hearing recovery in patients with SNHL.

PTA – Post and Pre treatment

PTA was performed on the day of admission or before the treatment and results were noted in patient case sheets and after treatment/ sessions on HBOT, tone audiogram result were obtained and noted (Fig-

1).Patient with, complete, partial, slight recovery were identified after PTA as per Siegel's criteria.

Results

This study evaluated the effectiveness of Hyperbaric Oxygen Therapy (HBOT) in improving hearing thresholds for patients with sensorineural hearing loss. Data from 71 patients were analyzed, comparing pre-therapy and post-therapy air and bone conduction thresholds across six frequencies (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz). (Fig 1 and 2)

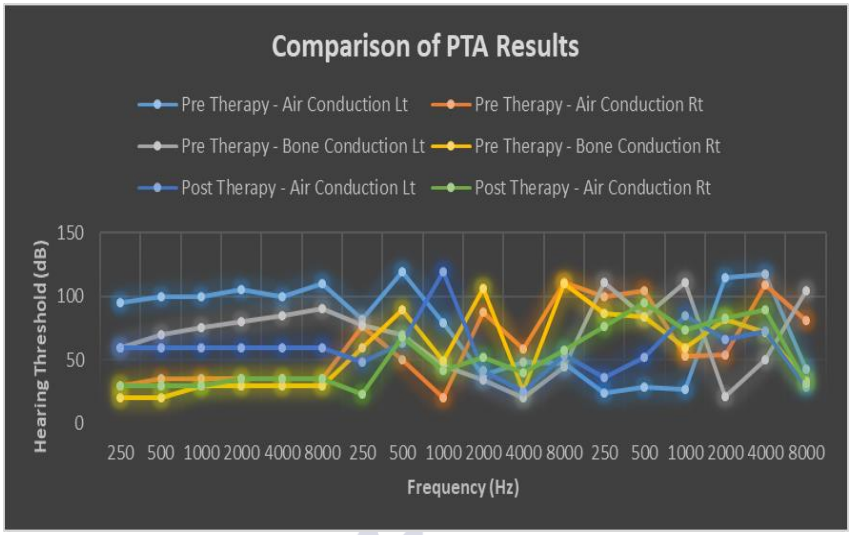

Fig 1: Comparison of PTA Results

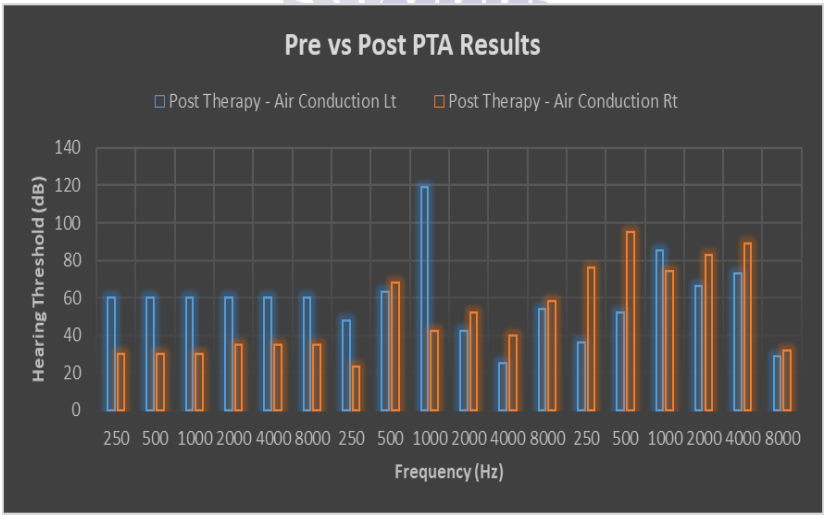

Fig 2: Pre vs Post PTA Results

Key Findings

Improvements in Hearing Thresholds. Significant improvements were observed in air conduction thresholds, particularly at lower frequencies (250 Hz and 500 Hz). For example, some patients showed improvements of up to 40–50 dB in air conduction thresholds. Bone conduction thresholds showed less improvement, with many patients exhibiting no change post-therapy.

Frequency-Specific Effects. The greatest improvements were noted at lower frequencies (250 Hz and 500 Hz), while higher frequencies (4000 Hz and 8000 Hz) showed minimal or no improvement.

This suggests that HBOT may be more effective for low-frequency hearing loss.

Patient Variability. While many patients experienced significant improvements (Fig.3), others showed no change in hearing thresholds, indicating that the effectiveness of HBOT may vary depending on individual patient factors.

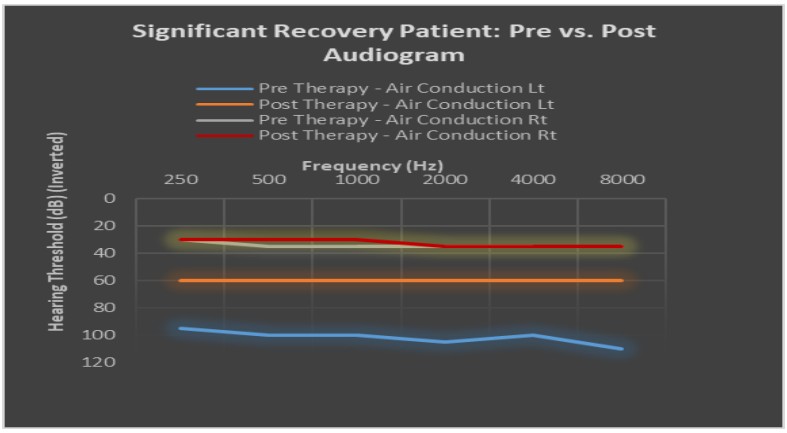

Fig 3: Significant Recovery Patient: Pre vs. Post Audiogram

Overall Effectiveness. Approximately 60–70% of patients showed some degree of improvement in air conduction thresholds, while bone conduction thresholds remained largely unchanged. Overall HBOT efficiency was 39 % (Fig 4).

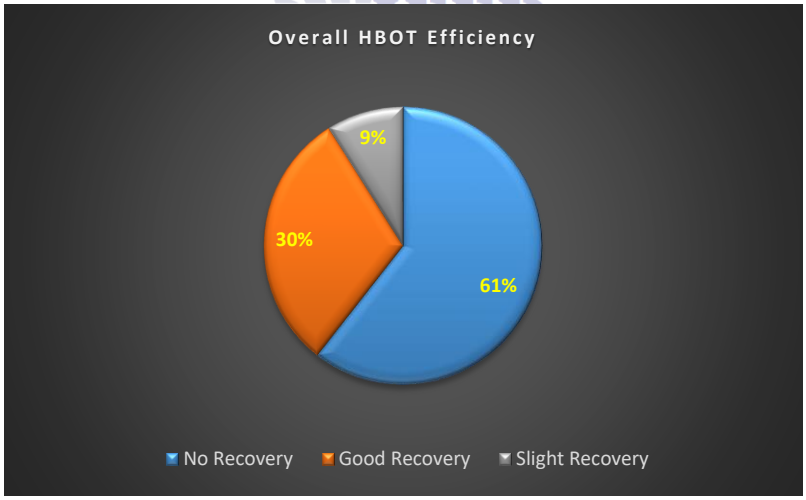

Fig 4: Overall HBOT Efficiency

These results support the potential use of HBOT as a therapeutic option for sensorineural hearing loss, particularly in cases involving low-frequency air conduction deficits. Future studies with larger sample sizes, controlled designs, and long-term follow-ups are recommended to validate these findings and explore the underlying mechanisms of HBOT in hearing restoration.

DISCUSSIONS

It is important to recognize the various limitations of this study. The first major issue was the scarcity of hyperbaric oxygen therapy (HBOT) chambers in Karachi; only one operational chamber was available for the study. Many patients experienced delayed appointments as a result, potentially jeopardizing the promptness of treatment. HBOT works best when

given early, especially within the first two weeks of symptom onset; for some patients, these delays may have decreased the therapy's overall effectiveness. Second, because only one center was used for the study, the results may not be as applicable to other populations or healthcare environments. Third, future research with larger cohorts is required to validate these findings, even though the sample size was sufficient for preliminary analysis. Furthermore, there was no control group in the study, which makes it challenging to compare HBOT's results with those of other treatment modalities or no treatment at all. Lastly, the follow-up period was brief, and it is still unknown how HBOT will affect sensorineural hearing loss in the long run. These restrictions emphasize the necessity for further research in larger, multicenter studies with improved access to HBOT facilities to better understand the therapy's effectiveness and optimize treatment protocols.

Adverse Events and Management

On the third day of treatment in the HBOT experiment, three patients had excruciating unilateral ear pain. One ear was the only one experiencing the severe, ongoing agony. All three patients were assessed right away, and an otoscopic examination revealed no evidence of tympanic membrane perforation or barotrauma.

Management and Follow-Up

To treat possible Eustachian tube dysfunction and lower inflammation, the patients received antihistamines and the nasal decongestant xylometazoline for a week. In order to avoid more issues, HBOT was temporarily stopped during this time. The patients' symptoms did not significantly improve in spite of these therapies, and the ear ache continued.

Outcome

For all three patients, HBOT was permanently stopped due to the lack of progress and the intensity of the discomfort. After stopping HBOT, the ear pain gradually went away in two weeks, according to follow-up assessments, and no long-term issues were noted.

Discussion of the Incident

This event draws attention to the possible risk of HBOT, especially in patients who could be more susceptible to middle ear issues or Eustachian tube malfunction. Given that the ear pain was unilateral, it is possible that localized pressure changes during HBOT played a role in the discomfort. The need for rigorous patient screening and monitoring during HBOT studies is further highlighted by the absence of improvement with antihistamines and decongestants.

Implications for Future Research

To identify patients who are more likely to experience such adverse effects, future research should think about using pre-treatment otologic examinations. Alternative procedures could help reduce these hazards, such as using tympanostomy tubes in vulnerable people or slower compression rates.

The scarcity of HBOT chambers in Karachi draws attention to a larger problem with Pakistan's distribution of healthcare resources. Hyperbaric oxygen therapy is a resource-intensive procedure that calls for skilled workers and specific equipment. Particularly for time-sensitive situations like SSNHL, the existing dependence on a single chamber in a city with over 20 million residents is not enough to handle the demand. To solve this issue, policymakers and healthcare administrators ought to think about taking the following actions:

Infrastructure Investment: To guarantee fair access for all patients, expand the number of HBOT chambers in large cities, especially in public hospitals.

Education and Training: To increase the number of competent individuals who can deliver the therapy, train medical professionals in its application.

Public-Private Partnerships: To build more HBOT facilities, promote partnerships between public and private healthcare providers.

Awareness campaigns: Inform the public and medical professionals about the advantages of HBOT and the significance of prompt treatment for illnesses such as SSNHL.

CONCLUSION

Before beginning treatment, every patient in this trial had severe to profound hearing loss. According to the

results, patients with sensorineural hearing loss (SNHL) may benefit from Hyperbaric Oxygen Therapy (HBOT) to a moderate extent, especially when it comes to air conduction at lower frequencies (250 Hz and 500 Hz). With no effect on high-frequency thresholds or bone conduction, the treatment seems to be more helpful for low-frequency hearing loss. The need for more research to pinpoint particular patient subgroups that might benefit the most from HBOT is highlighted by the variation in patient responses.

Three patients had severe unilateral ear discomfort during HBOT sessions during the research; this pain remained even after using antihistamines and nasal decongestants. This case emphasizes the possible dangers of HBOT, especially for individuals who already have middle ear or Eustachian tube dysfunction. It also highlights how crucial it is to carefully assess patients and keep an eye on them when administering HBOT in order to minimize side effects. In order to identify patients who are more likely to experience these consequences, future research should incorporate pre-treatment otologic examinations. Additionally, alternate protocols, including slower compression rates or the use of tympanostomy tubes, should be investigated in order to increase safety.

For many patients, the lack of HBOT chambers in Karachi—there is only one operational chamber that serves the entire city—posed a serious obstacle to receiving timely therapy. Since early intervention is essential for the best results, HBOT's efficacy may have been harmed by appointment scheduling delays. This problem emphasizes how urgently infrastructural improvements and regulatory changes are required to increase access to HBOT in Pakistan. To guarantee fair access for patients with time-sensitive illnesses like sudden sensorineural hearing loss (SSNHL), policymakers and healthcare executives should think about funding more HBOT facilities, especially in large cities. Enhancing the accessibility and use of HBOT may also be greatly aided by public-private collaborations and awareness initiatives.

To further confirm HBOT's effectiveness in SNHL, future research should concentrate on bigger, multicenter studies with controlled settings. Subgroup studies should be performed to determine which patient features are predictive of a positive response to HBOT, and long-term follow-ups are required to evaluate the durability of hearing improvements. To create evidence-based recommendations for the treatment of SNHL, research contrasting HBOT with alternative therapy approaches, including corticosteroids or combination therapies, is also required.

In summary, HBOT exhibits potential as a treatment for sensorineural hearing loss, especially low-frequency hearing loss; nevertheless, its efficacy depends on a number of variables, such as patient selection, timely delivery, and accessibility to treatment centers. Optimizing the use of HBOT and improving outcomes for individuals with SNHL will need addressing these issues through enhanced infrastructure, patient screening, and additional research.

Ethics Committee Approval

All subjects provided written consent for their treatments with HBOT. The study was conducted in accordance with the Helsinki Declaration and the research was approved by the Research Evaluation Unit, College of Physicians and Surgeons Pakistan (CPSP) (Ref No: CPSP/REU/ENT-2022-197-1410, Dated: October 25, 2023). The approval was granted for the dissertation topics: "Efficacy of Hyperbaric Oxygen Therapy in Sensorineural Hearing Loss" granted for the dissertation topics: "Efficacy of Hyperbaric Oxygen Therapy in Sensorineural Hearing Loss". The approval was signed by **Dr. Muhammad Tariq Karim, Assistant Professor & Head, Research Evaluation Unit, CPSP.**

Informed Consent

All patients who met the inclusion criteria and were interested in participating in this prospective trial signed an informed consent form.

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Conflict of Interest
The authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

Dr Huzaifa Usman (Resident)
Coordination of collaborative efforts.
Study Design, Review of Literature.

SOHAIL ASLAM (HOD of ENT)
Conception of Study, Development of Research Methodology Design, Study Design, Review of manuscript, final approval of manuscript.
Conception of Study, Final approval of manuscript.

Dr Naseer Ahmed (Associate Professor)
Manuscript revisions, critical input.
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Manuscript drafting.

Dr Asif Gul (Associate Professor)
Data entry and Data analysis, drafting article.

Dr Rimsha Younus (ENT Resident)
Data acquisition, analysis.
Coordination of collaborative efforts.

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