

## THE INFLUENCE OF HYPERBARIC OXYGEN THERAPY ON COCHLEAR PERCEPTION IMPROVEMENT IN SUDDEN DEAFNESS: LITERATURE REVIEW

*Pengaruh Terapi Oksigen Hiperbarik Terhadap Perbaikan Persepsi Cochlear  
Pada Sudden Deafness: Literature Review*

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### ABSTRAK

Gangguan pendengaran mendadak diketahui menjadi salah satu gangguan pendengaran yang sering terjadi dengan jumlah kasus berkisar 80% hingga 90% kasus, dan mayoritas berdampak pada gangguan pendengaran mendadak di salah satu telinga. Kasus gangguan pendengaran mendadak diketahui dapat disembuhkan melalui manajemen yang sesuai. Kelainan vaskuler, kelainan imunologi, infeksi akibat virus serta rusaknya membran koklea dinilai sebagai faktor penyebab gangguan pendengaran. Salah satu manajemen gangguan pendengaran mendadak yang sering dilakukan dalam jangka waktu pendek adalah terapi oksigen hiperbarik. Terapi oksigen hiperbarik pada pasien gangguan pendengaran mendadak sebagai salah satu manajemen penanganan gangguan pendengaran mendadak bekerja melalui mekanisme peningkatan distribusi oksigen pada koklea. Penelitian ini disusun dengan tinjauan literatur sistematis untuk mengevaluasi pengaruh terapi oksigen hiperbarik terhadap perbaikan gangguan pendengaran mendadak. Peneliti memilih sampel dari jurnal internasional dan nasional yang terindeks oleh ProQuest, Wiley Online, Science Direct, Taylor Francis, SAGE, PubMed, dan SINTA antara tahun 2017 dan 2022. Peneliti menyadari kurangnya literatur yang relevan karena hanya 11 jurnal yang sesuai dengan kriteria penelitian. Namun, ini dianggap sebagai langkah awal untuk penelitian lebih lanjut. Temuan menunjukkan bahwa terapi oksigen hiperbarik berpengaruh terhadap perbaikan persepsi koklea pada pasien yang mengalami gangguan pendengaran mendadak, setelah pemberian terapi dengan rata-rata waktu 1-2 minggu, dengan tekanan 1,8 ATA hingga 2 ATA, baik dikombinasikan dengan kortikosteroid maupun terapi oksigen hiperbarik saja. Rekomendasi penulis adalah penelitian selanjutnya dapat meneliti faktor yang memengaruhi efektivitas pemberian terapi oksigen hiperbarik terhadap perbaikan gangguan pendengaran mendadak serta pemberian terapi oksigen hiperbarik dapat menjadi salah satu terapi adjuvan yang dapat diberikan kepada pasien di Indonesia.

**Kata Kunci:** gangguan pendengaran mendadak, koklea, terapi oksigen hiperbarik

### ABSTRACT

Sudden deafness is known to be one of the common hearing disorders, accounting for approximately 80 to 90% of cases, with the majority affecting one ear. Cases of sudden hearing loss are known to be treatable through appropriate management. On the other hand, vascular abnormalities, immunological disorders, virus-related infections, and

cochlear membrane damage are considered causative factors of hearing impairment. One of the frequently used short-term management strategies for sudden hearing loss is hyperbaric oxygen therapy. Hyperbaric oxygen therapy in patients with sudden hearing loss works through the mechanism of enhancing oxygen distribution in the cochlea. This research was structured with a descriptive design and systematic literature review to evaluate the impact of hyperbaric oxygen therapy on sudden hearing loss improvement. Samples were drawn from international and national journals indexed by ProQuest, Wiley Online, Science Direct, Taylor Francis, SAGE, PubMed, and SINTA between 2017 and 2022. Researchers acknowledged the lack of relevant literature because only 11 journals meeting the research criteria. However, this was considered a preliminary step for further investigation. Findings indicate that hyperbaric oxygen therapy influences cochlear perception improvement in patients experiencing sudden hearing loss after therapy administration averaging one to two weeks, at pressures ranging from 1.8 ATA to 2 ATA, whether combined with corticosteroids or used alone. The author's recommendation is for further research to explore various factors affecting the effectiveness of hyperbaric oxygen therapy in improving sudden hearing loss and that hyperbaric oxygen therapy could be one of the adjunctive therapies provided to patients in Indonesia.

**Keywords:** sudden deafness, cochlea, hyperbaric oxygen therapy

## INTRODUCTION

Deafness is the loss of the ability to hear sounds within the normal hearing threshold range of 20db. Deafness can affect one or both ears so sufferers have difficulty in hearing conversational speech or loud sounds.<sup>1</sup> Deafness can be categorized into three types referring to the classification according to the American Academy of Otolaryngology and Neck Surgery, namely conductive deafness, sensorineural deafness, and deafness which is a mixture of conductive and sensorineural deafness.<sup>2</sup> Conductive deafness is defined as deafness in the form of obstruction of the conduction of sound waves through the outer ear, tympanic membrane, or middle ear due to abnormalities in part or all of the ear structure.<sup>2</sup> Sensorineural deafness is defined as a condition of deafness due to abnormalities in the function of the cochlea and other structures that play a role in processing neural impulses to the auditory cortex.<sup>2</sup>

Sudden deafness is a condition of sudden decline in hearing ability or deafness which is characterized by a loss of sensitivity to hear at least 30 dB measured at more than three

frequencies sequentially that occurs within 72 hours.<sup>2</sup>

This can also be further identified at intervals of a maximum of three days. Sudden deafness can be classified into sudden deafness with a known cause and sudden deafness with an unknown cause.<sup>3</sup> In research conducted by Yoshida (2017), idiopathic deafness is the most frequently encountered case with a worse recovery rate than acute deafness.<sup>3</sup> Sudden deafness is a condition that occurs suddenly and immediate therapy is recommended<sup>2</sup>. Sudden deafness is usually unilateral and less than 2% is bilateral.<sup>4</sup>

The prevalence rate of Sudden deafness globally in 2022 is known to occur in 5 to 20 out of 100,000 individuals per year.<sup>5</sup> Sudden deafness is known to be one of the most common types of deafness, about 80 to 90% of cases in number, and the majority of cases result in sudden deafness in one ear.<sup>1</sup>

Cases of sudden deafness are known to be curable through appropriate management. Management of sudden deafness can refer to its etiology, though the etiology of the factors causing sudden deafness is still uncertainly known. The selection of hyperbaric

oxygen therapy for the management of sudden deafness is based on its effectiveness in increasing oxygen supply to the affected tissues, reducing inflammation, having minimal risk of side effects, and being clinically proven effective, making it a preferred choice compared to other available therapies. On the other hand, vascular and immunological abnormalities, viral infections and cochlear membrane damage are considered factors causing deafness.<sup>6,7</sup> These four etiologies are known to contribute to permanent and irreversible cochlear damage. Meanwhile, most cases of sudden deafness are known to be reversible. Therefore, the sudden deafness condition becomes an otological emergency requiring immediate comprehensive sudden deafness management.<sup>6,7</sup>

One of the sudden deafness management that is often carried out in a short period is hyperbaric oxygen therapy.<sup>8</sup> Hyperbaric oxygen therapy was first introduced by Goto and carried out by providing 100% pure oxygen in a High-Pressure Air Chamber (RUBT) or high-pressure air chamber with a pressure of more than 1 ATA (Absolute Atmosphere) or equal to 760 mmHg, that is 2, 4 ATA in 60 to 120 minutes. This is done as the increasing pressure on oxygen is known to push the oxygen distribution acceleration in the body. During hyperbaric oxygen therapy, the increase in oxygen pressure enhances the amount of dissolved oxygen in the blood, improving tissue perfusion and providing a greater oxygen supply to the cochlea. Physiologically, this reduces ischemia and inflammation within the cochlea, allowing for the gradual improvement of damaged cochlear membrane and sensory hearing cells, thus alleviating sudden deafness.<sup>9</sup>

Hyperbaric oxygen treatment in unexpected hearing misfortune patients is one of the abrupt hearing misfortune treatment administrations managing the

component of expanding oxygen conveyance in the cochlea. Past investigations directed on patients with unexpected hearing misfortune showed that hyperbaric oxygen treatment had huge results suggestions, remembering complex impacts for the body.<sup>9</sup>

Giving hyperbaric oxygen therapy to twenty-eight patients in China was also known to have implications for improving microcirculation in the cochlea.<sup>10</sup> Providing hyperbaric oxygen therapy is also considered to have advantages because it is not invasive, hope that patients can feel comfortable during the therapy.<sup>9</sup>

Based on the explanation above, researchers are interested in conducting more in-depth learning through literature study methods focusing on providing hyperbaric oxygen therapy to patients with sudden deafness. Researchers will analyze the dosage of pressure and time given to hyperbaric oxygen therapy by observing improvements in cochlear perception in sudden deafness, so that the effectiveness of hyperbaric oxygen therapy can be determined. This research will focus on the title "The Effect of Hyperbaric Oxygen Therapy on Improving Cochlear Perception in Sudden Deafness "

Vasodilator is used to increase blood flow to the inner ear. Some of the vasodilator agents used are histamine, papaverine, verapamil, and carbogen. Although some studies show the benefits of vasodilator use, there is still limited clear evidence and the effects are not always consistent.

Hemodilution is an effort to reduce blood viscosity and optimize blood flow to the inner ear. Dextran, pentoxifylline, mannitol, and heparin are some of the agents used in hemodilution. However, the effectiveness of hemodilution is still debated and its administration is not always common practice.

Other therapy options include hyperbaric oxygen, which involves administering oxygen at high pressure.

This therapy is carried out in a High-Pressure Air Chamber (RUBT) or Hyperbaric Chamber and has a positive effect on ischemia and inner ear microcirculation conditions. However, the use of hyperbaric oxygen therapy as an adjunct therapy remains controversial and is not always routinely adopted. In principle, hyperbaric oxygen therapy has been recognized as adjunctive therapy. Hyperbaric oxygen therapy is actually the one with the best evidence-based medicine in diving diseases and clinical diseases, including sudden deafness, and it is used as adjunctive therapy. To strengthen this, the author chose this case of sudden deafness to reinforce the existing description in the use of hyperbaric oxygen therapy, thus minimizing the controversy that arises. This research is conducted to affirm and minimize the existing controversy.

Medicamentosa treatment may similarly incorporate antivirals like acyclovir and valacyclovir, especially if the startling hearing disaster is achieved by a viral defilement. Be that as it may, there is as yet deficient proof to help the viability of antivirals and their utilization has not been entirely tried.

Unexpected hearing mishap, which are impacted by host, trained professional and environmental components, happens due to receptiveness to uproar in the work environment, age, direction, race and genetic factors (have factors), as well as biological agents such as viruses and bacteria (agent factors). Environmental factors, consisting of extrinsic and intrinsic factors, also play a role, with most sudden deafness caused by vascular disorders triggered by viruses, bacteria, noise, and environmental factors outside the body, causing injury to the vascular endothelium of the inner ear. This injury induces an inflammatory reaction by chemical factors such as histamine, leucotriene, prostaglandin, bradykinin, and serotonin. Although anti-

inflammatory mediators aim to protect tissue from infection, inflammatory reactions can also cause deafness due to blood flow hypoperfusion, and increased plasma and blood viscosity. The treatment of sudden deafness involves medicamentosa therapy, hyperbaric oxygen therapy, or a combination of both, which can result in improved hearing function depending on the intensity and hearing threshold. The research aimed to analyze and find out the effect of hyperbaric oxygen therapy on improving cochlear perception in sudden deafness.

## METHODS

Researchers used a systematic literature review aimed at identifying, evaluating and interpreting the findings of primary studies.<sup>11</sup> The samples in this research consist of reputable international journals that demonstrate the influence of hyperbaric oxygen therapy on the improvement of sudden hearing impairment. These journals have been indexed by ProQuest, Wiley Online, Science Direct, Taylor Francis, SAGE, and PubMed. Additionally, national journals indexed by SINTA (Science and Technology Index) and published between 2017 and 2022, The following represents a search for articles based on the PRISMA diagram, According to PRISMA, the minimum number of journals should usually be sufficient to achieve an adequate representation of relevant literature. This number may vary depending on the breadth of the research topic and the availability of relevant literature. Additionally, decisions regarding the minimum number of journals can also be influenced by the research objectives, methodological considerations, and the need to ensure the reliability and validity of findings with a minimum of 11 journals meeting the specified inclusion and exclusion criteria included. For the justification of the journal research, we used the suitability parameter from existing literature regarding the usage or

cases related to hyperbaric oxygen therapy with sudden deafness, as this usage is still rare and not widely adopted. Therefore, the actual justification was only 15 journals. However, considering the insufficient number of literature related to this title, it can be accepted to become a basic modality for further research.

In establishing inclusion criteria for the research, several aspects need to be considered. Firstly, selected journals must contain therapeutic worksheets used for populations of patients experiencing sudden hearing impairment and undergoing hyperbaric oxygen therapy alongside medication intervention. Secondly, these journals should be indexed in databases such as ProQuest, Wiley Online, Science Direct, Taylor Francis, SAGE, and PubMed. Thirdly, national journals listed in SINTA (Science and Technology Index) can also be included as sources. Finally, the

journals used must be published within the timeframe of 2017 to 2022. However, to ensure research quality, several exclusion criteria also need to be applied. These include case reports, editor letters, and editorial notes. Additionally, non-analytical journals are excluded from selection as they do not meet the required standards of analysis in scientific research. By utilizing these inclusion and exclusion criteria, it is hoped that the resulting research will provide valuable and relevant insights into the effectiveness of hyperbaric oxygen therapy for patients with sudden hearing impairment.

The following represents a search for articles based on the PRISMA diagram. The method employed is the PICO method, followed by analysis using the CASP tool. For further clarity, it is depicted in the following diagram in Figure 1.

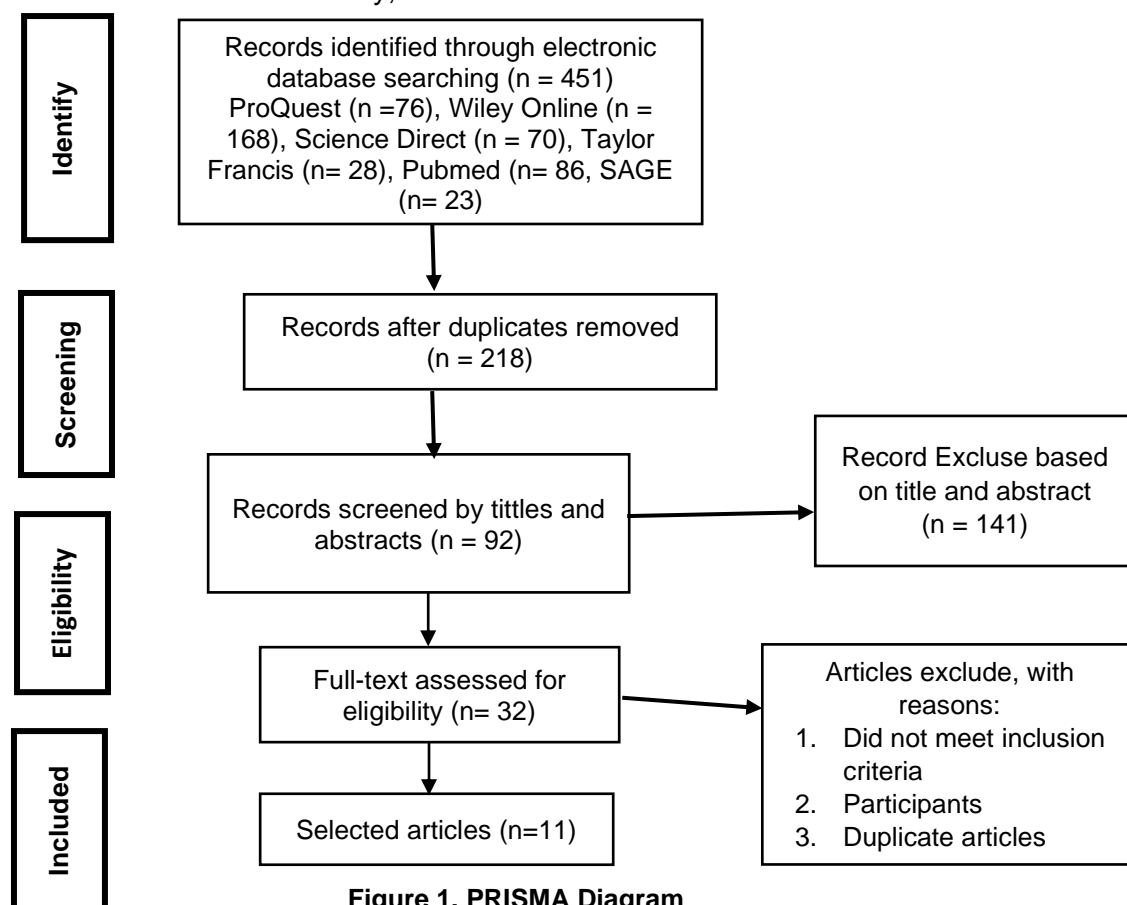


Figure 1. PRISMA Diagram

The study's data collection process followed a structured sequence. Initially, 451 journals were scrutinized to identify pertinent issues concerning sudden deafness, hyperbaric oxygen therapy (HBOT), and methods to enhance cochlear function. Subsequently, a comprehensive search for both national and international literature pertaining to these topics was conducted across various databases, including ProQuest, Wiley Online, Science Direct, Taylor Francis, SAGE, and PubMed. This search, spanning publication years from 2017 to 2022, yielded 219 relevant journals. Following the acquisition of literature, data analysis was performed on the collected journals, involving a meticulous examination of 32 publications to derive insights and patterns. Finally, reports summarizing the analyzed data were generated, consolidating key findings from 11 journals. This systematic approach facilitated a comprehensive understanding of the targeted subjects and provided valuable insights for further research and clinical applications.)

After the completion of data collection, the next phase involves several key data processing steps. Initially, a thorough examination of national and international journal articles is conducted. Subsequently, the gathered data is consolidated and categorized based on predetermined inclusion and exclusion criteria. The outcomes and conclusions derived from this process are then systematically organized into a research table format. This table includes essential details such as author names, journal titles, types of

journals, publication periods, hyperbaric oxygen therapy characteristics, characteristics of patients experiencing sudden hearing impairment, and the overall findings of the research. This structured approach facilitates a comprehensive analysis of the collected information, ensuring a systematic and organized presentation of the study's outcomes.

The technique is to combine primary research results to provide more accurate and clear facts, namely by collecting libraries in the form of scientific articles sourced from valid databases that are relevant to the variables and objectives of this research.<sup>12</sup> Researchers will highlight the main findings revealed in the articles reviewed, including making observations on advantages, disadvantages, differences or similarities, as well as comparing previous research and research results<sup>12</sup> Research diary proficiency procedures, utilizing basic audit strategies with remedial worksheets. Method utilized ought to be joined by references, and significant change ought to be made sense of. Method and information investigation procedure ought to be underlined to writing the survey article. The technique ought to contain sufficient detail to empower the peruser to assess the fittingness of your strategy and the dependability and legitimacy your discoveries. Besides, the data ought to empower experienced scientists to duplicate your review.<sup>13</sup> Instead of being part of the image itself, the description is included in the image's title (caption). The techniques utilized in the exploration written in this segment.

RESULT

No	Author, Year Title, Location	Purpose	Method	Result
1	Feng, X., Dong, S., Wang, J., Yang, J., Wang, Y., Zhang, D.,	The study aimed to investigate the clinical efficacy of	<b>Design:</b> Retrospective cohort <b>Analysis:</b> The analysis utilized a comparative approach, examining the effects of hyperbaric oxygen treatment on two groups receiving	The results of this study demonstrated that the overall effectiveness of 1.8 ATA hyperbaric oxygen therapy in study group 1 was 90.00%,

No	Author, Year Title, Location	Purpose	Method	Result
	Guangjun, P & Luo, J., (2022)  Clinical Efficacy of Hyperbaric Oxygen Therapy at Different Pressures in the Treatment of Sudden Deafness  Affiliated Hospital of Hebei University	hyperbaric oxygen at various pressures for treating sudden deafness in patients selected from the Affiliated Hospital of Hebei University, aiming to offer insights for clinical practice..	different pressures (1.8 ATA and 2.2 ATA) alongside routine care. Each group underwent two courses of treatment lasting 10 days, with oxygen administered via a pressure stabilizing mask for 60 minutes <b>Instrument:</b> Patients were randomly divided into 2 groups. Group 1 consisted of 22 male patients and 18 female patients, with an average age of 21-65 years and an onset period of 3 hours to 30 days. Group 2 comprised 19 male patients and 23 female patients, with an average age of 20-65 years and an onset period of 5 hours to 30 days. Both groups received hyperbaric oxygen therapy with a pressure of 1.8 ATA in Group 1 and 2.2 ATA in Group 2. "With a total sample size of 82 patients, the result of $p=0.039$ indicates that hyperbaric oxygen therapy is effective in both groups."	while in study group 2 with 2.2 ATA, it was 76.19%. The effectiveness in study group 1 was significantly higher than that in study group 2 ( $p < 0.05$ ). There was no significant difference in the hearing threshold between the two groups before treatment ( $p > 0.05$ ). Post-treatment, the hearing threshold decreased in both groups, with significantly greater improvement observed in study group 1 compared to study group 2 ( $p < 0.05$ ). These findings suggest that hyperbaric oxygen therapy at 1.8 ATA has a more pronounced therapeutic effect on sudden deafness, potentially enhancing inner ear circulation, augmenting oxygen delivery, and achieving an optimal restoration of hearing levels in patients.
2	Chin, C., Lee, T., Chen, Y., & Wu, M (2022)  Idiopathic Sudden Sensorineural Deafness : Is Hyperbaric Oxygen Treatment the Sooner and Longer, the Better?  in aichung Veterans General Hospital	This study aimed to evaluate the hearing gain efficacy from HBO therapy in ISSHL patients	<b>Design:</b> Retrospective cohort study <b>Analysis:</b> A retrospective chart review was conducted on patients with sudden sensorineural hearing loss (ISSHL) between January 2016 and December 2021. Patients referred for hyperbaric oxygen (HBO) therapy by the ENT department were evaluated for hearing gain using pure-tone audiometry. Analysis included 102 patients after 1 to 5 therapy sessions and 46 patients after 6 to 10 sessions. <b>Instrument:</b> The patients, comprising 81 males and 67 females with an average age of 52.2, underwent hyperbaric oxygen therapy intervention for 13 days, resulting in a Pure Tone Audiometry (PTA) of 68 dB. Treatment involved intratympanic steroid administration for 113 patients and oral steroid usage for 110 patients. All 148 patients received some form of steroid treatment.	Patients undergoing hyperbaric oxygen therapy were divided into two groups: 102 patients receiving therapy for 1-5 sessions and 46 patients for 6-10 sessions. The research results demonstrated that hyperbaric oxygen therapy exhibited improvement based on Pure Tone Audiometry (PTA) outcomes with the odds ratio for the age factor being 0.976 and a p-value of 0.270. The odds ratio for the severity of hearing impairment, ranging from moderate to severe, was 2.267 with a p-value of 0.132, and from severe to moderate, it was 5.034 with a p-value of 0.002. Patients undergoing intervention within <12 days or >13 days had an odds ratio of 6.484 with a p-value of 0.000. Based on the analysis of the intervention time between the onset of sudden deafness and the commencement of hyperbaric oxygen therapy in each patient group, those who received only 1-5 sessions

No	Author, Year Title, Location	Purpose	Method	Result
				(N=102) showed an increase in hearing of 20.5 dB and a recovery of 41.6% after 12 days of hyperbaric oxygen therapy, compared to those who received additional therapy in the second round of 6-10 sessions (N=20) after 13 days, with an increase in hearing of only 3 dB and a recovery of 9.4%. However, both comparisons did not indicate further benefits.
3	Ahn, Y., Seo, Y. J., Lee, Y. S. (2021)  The Effectiveness of Hyperbaric Oxygen Therapy in Severe Idiopathic Sudden Sensorineural Deafness,	In this study, we investigated the necessity of routine application of combined steroid therapy and HBOT for severe or profound ISSNHL and attempted to define the indications of hearing thresholds on PTA for HBOT	<b>Design:</b> Retrospective cohort study <b>Analysis:</b> (ANOVA) and Chi-Squared test. <b>Sample:</b> Derived from 218 patients with severe sudden deafness . <b>Instrument:</b> The hearing impairment group, consisting of patients with deafness >80 dB, included 47 patients treated with oral steroids only (PO) with an average age of 56.85, 62 patients treated with oral steroids (PO) and intratympanic dexamethasone injections (IT) with an average age of 52.18, and 37 patients treated with hyperbaric oxygen therapy, oral steroids, and intratympanic dexamethasone injections (PO+IT+HBOT) with an average age of 53.32. Meanwhile, the group with hearing impairment of 60-79 dB, comprising 27 patients treated with PO with an average age of 52, 18 patients treated with PO+IT with an average age of 50 years, and 16 patients treated with (PO+IT+HBOT) with an average age of 55 years.	Hyperbaric oxygen therapy is administered 10-20 times for 100 minutes per day using 100% pure oxygen for ventilation at 2 ATA based on hospital protocols. Oral steroid therapy begins on day 5 with a high dose of methylprednisolone (48mg) and is gradually tapered over 5 days. Intratympanic injection (5 mg/mL) is also performed. The initial Pure Tone Audiometry (PTA) threshold greater than 80 dB shows no significant difference (P = 0.074). The gap between the initial and final PTA is 44.12 ± 28.19 dB in the PO group, 40.77 ± 31.55 dB in the PO+IT group, and 27.7 ± 26.74 dB in the HBOT group, indicating a lower hearing recovery value in the HBOT group (P = 0.076). Statistical analysis between groups for each PTA frequency did not yield significant results.
4	Chrisna, S., Savitri, P. M., & Harjono, Y (2021)  Hubungan Usia, Derajat Ketulian, dan Onset Tuli Mendadak dengan Perbaikan Pendengaran setelah	This study aims to determine the relationship between age, degree of hearing loss, tinnitus, and sudden deafness onset with hearing improvement after HBOT	<b>Design:</b> Cross-sectional <b>Analysis:</b> SPSS statistical analysis and Fisher's test <b>Sample:</b> The study involved 36 randomly selected patients. <b>Instrument:</b> The sample consisted of 20 male and 16 female patients, with an average age of less than 50 years. The therapy was administered for 10 sessions in 26 patients. The degree of hearing impairment was moderate in 12 patients and severe in 24 patients. Onset of symptoms was less than 7 days in 29 patients	The research results, utilizing Fisher's test, indicate that there is no correlation between the degree of hearing impairment and improvement (p = 0.307), and the onset of sudden deafness as a prognostic factor is not associated with hearing improvement (p = 0.559).

No	Author, Year Title, Location	Purpose	Method	Result
	Hyperbaric Oxygen Therapy  at Dr. Mintohardjo Naval Hospital from 2016 to 2019.		and more than 7 days in 7 patients. No improvement in hearing was observed in 5 patients, while 31 patients showed improvement in hearing.	
5	Choi, Y., Choi, H.L., Jeong, A. Y., Kang, W.S., Park, H.J., Chung, J.W., & Ahn, J.H (2020)  Hyperbaric oxygen (HBO) therapy as an effective approach to the treatment of patients with severe idiopathic sudden sensorineural deafness	To evaluate the efficacy of HBO therapy.	<b>Design:</b> Retrospective cohort study <b>Analysis:</b> SPSS statistical analysis, and both groups were compared using Fisher's exact test and the Student's t-test. <b>Sample:</b> The study included 82 patients (83 ears) diagnosed with sudden deafness . <b>Instrument:</b> Patients underwent hyperbaric oxygen therapy for 14 sessions, divided into two control groups (receiving only intratympanic steroid therapy) comprising 16 male and 22 female patients with an average age of 60.2. Meanwhile, the treatment group (receiving hyperbaric oxygen therapy and intratympanic steroid therapy) consisted of 25 male and 20 female patients with an average age of 55.6 over a two-week period.	The research results on the use of W4FA revealed a significant improvement in hearing frequency ( $p = <0.05$ ) in the group receiving hyperbaric oxygen therapy ( $28.1 \pm 26.9$ dB) compared to the control group ( $14.8 \pm 13.5$ dB). Hyperbaric oxygen therapy proves to be an effective choice for the initial treatment of patients experiencing sudden deafness .
6	Tong, B., Niu, K., Ku, W., Dai, Q., Hellstrom, S., & Duan, M. (2020)  Comparison of Therapeutic Results with/without Additional Hyperbaric Oxygen Therapy in Idiopathic Sudden Sensorineural Deafness : A Randomized Prospective Study.	Aim in this research To investigate the necessity of routine application of hyperbaric oxygen therapy for sudden sensorineural hearing loss	<b>Design:</b> Retrospective cohort study <b>Analysis:</b> trial involving 136 cases with unilateral ISSNHL that were randomly divided into 2 groups: the pharmacological treatment (P) group and HBO + pharmacological treatment (HBO+P) group, which received additional HBO for 14 days besides the pharmacological treatments. Pure tone audiometry gain larger than 15 dBHL was defined as success, and the success rate of each group was calculated <b>Sample:</b> Data were obtained from 136 cases of sudden deafness . <b>Instrument:</b> Divided into 2 groups; the pharmacological therapy group consisting of 41 male and 29 female patients with an average age of 43.88, while the pharmacological therapy and hyperbaric oxygen therapy group consisted of 35 male and 31 female patients with an average age of 40.25.	The research results indicate a success rate of 60.6% for the pharmacological therapy and hyperbaric oxygen therapy group, compared to 42.9% for the group receiving only pharmacological therapy. The pharmacological therapy and hyperbaric oxygen therapy group demonstrated a higher success rate than the group receiving only pharmacological therapy ( $p <0.05$ ). Therefore, the combination of drug therapy with pharmacological treatment appears to be more effective.

No	Author, Year Title, Location	Purpose	Method	Result
7	Eski, E., Babakurban, S., Yilmaz, S., Yilmazer, C., Erkan, A.N., Caylakli, F., & Yilmaz, I (2020)  Comparing the Efficiencies of Hyperbaric Oxygen Therapy and Intratympanic Steroid Treatment for Sudden Deafness,  In Turkey	The aim this research To compare the efficiencies of hyperbaric oxygen therapy (HBOT) and intratympanic steroid (ITS)treatment for idiopathic sudden sensorineural hearingloss (ISSHL), Turkey	<b>Design:</b> Retrospective cohort <b>Analysis:</b> Statistical analysis using $\chi^2$ and Fisher's exact test. Due to the non-fulfillment of parametric distribution assumptions, continuous measurements were assessed using the Mann-Whitney U-test. A significance level of $p < 0.05$ was determined for statistical significance. <b>Sample:</b> Data were obtained from 136 patients with sudden deafness . <b>Instrument:</b> Thirty-three patients received Hyperbaric Oxygen Therapy (HBOT) and Systemic Steroid Therapy (SST), comprising 12 male and 21 female patients with an average age of 53 years. Meanwhile, 36 patients received Intratympanic Steroid Therapy (ITS) following SST, consisting of 14 male and 22 female patients with an average age of 54 years.	The research findings revealed no change in Hearing Gain (HG) determined between the HBOT and ITS treatment groups. However, the recovery time was higher in the ITS treatment cohort (40%) compared to the HBOT cohort (17%).
8	Krajčovičová, Z., Meluš, V., Zigo, R., Matišáková, I., Večeřa, J., Králová, E (2019)  Hyperbaric oxygen therapy in treatment of sudden sensorineural deafness : finding for the maximal therapeutic benefit of different applied pressures,  in Department of Otolaryngology, Faculty Hospital Trenčín, Slovakia, between July 2015 and June 2018	the main purpose of our present study was to compare the efficacy of HBO2 used in the treatment of SSNHL as a supplementary therapy to the firstline medical treatment according to the different applied pressures used in HBO2 therapy while maintaining the same number of sessions, periodicity and exposure times,	<b>Method:</b> <b>Design:</b> Retrospective cohort <b>Analysis:</b> Kruskal-Wallis statistical analysis was employed with post- test Dunn based on the chi-square test. A p-value less than 0.05 was considered statistically significant. <b>Sample:</b> Data were collected from 115 patients with sudden deafness . <b>Instrument:</b> Comprising 59 males and 36 females with an average age of 49 years experiencing sudden deafness , the patients were divided into 3 groups: the pharmacological therapy group (as the control group), the treatment group receiving pharmacological therapy and hyperbaric oxygen therapy at 2.0 ATA, and the treatment group receiving pharmacological therapy and hyperbaric oxygen therapy at 2.5 ATA.	Both treatment groups, when compared with the control group, received significantly better treatment. Hyperbaric oxygen therapy in combination with pharmacological (For the first five days of hospitalization patients received intravenous application of solumedrol) treatment at 2.5 ATA was found to be more effective at low frequencies (250 – 500 Hz), whereas at high frequencies (4000 – 8000 Hz), better hearing was achieved with the administration of hyperbaric oxygen therapy and pharmacological treatment at 2 ATA ( $p = 0.001$ ).
9	Hosokawa, S., Hosokawa, K.,	The aim of this study is to	<b>Method:</b> Design: Retrospective cohort and case control. <b>Analysis:</b>	In the HBOT + SS group, 42 out of 161 (26.1%) patients showed

No	Author, Year Title, Location	Purpose	Method	Result
	Takahashi, G., Sugiyama, K. I., Nakanishi, H., Takebayashi, S., & Mineta, H (2018)  Hyperbaric oxygen therapy as concurrent treatment with systemic steroids for idiopathic sudden sensorineural deafness : a comparison of three different steroid treatments,	compare the efficacy of HBO2 used in the treatment of idiopathic sudden sensorineural hearing loss as a supplementary therapy to the first-line medical treatment based on the different applied pressures used in HBO2 therapy while maintaining the same number of sessions, periodicity, and exposure times.	analyzed 356 patients with idiopathic sudden sensorineural hearing loss treated with hyperbaric oxygen therapy and systemic steroids (n = 161), systemic steroids alone (n = 160), or intratympanic and systemic steroids (n = 35). The main outcome measure was the hearing recovery rate.. Sample: Data were collected from 356 patients with sudden deafness . These patients experienced hearing impairment $\geq 30$ dB in three consecutive frequencies in standard pure-tone audiometry for $\leq 3$ days. <b>Instrument:</b> Treated with hyperbaric oxygen therapy and systemic steroids (n = 161) with a mean age of 59 years, including 86 male and 75 female patients. Systemic steroids alone (n = 160) with a mean age of 57 years, comprising 82 male and 78 female patients. Intratympanic and systemic steroids (n = 35) with a mean age of 56 years, including 18 male and 17 female patients.	total recovery, 41 (25.5%) showed good recovery, 42 (26.1%) showed fair recovery, and 36 (22.4%) showed no change. The overall hearing recovery rate was significantly higher in the HBOT + SS group (125/161 [78.3%]) compared to SS (52/160 [32.5%]; p <0.001) and IT + SS (17/35 [48.6%]; p <0,001).
10	Cavaliere M, De Luca P, Scarpa A, Strzalkowski AM, Ralli M, Calvanese M, Savignano L, Viola P, Cassandro C, Chiarella G, Di Stadio A (2022)  Combination of Hyperbaric Oxygen Therapy and Oral Steroids for the Treatment of Sudden Sensorineural Deafness : Early or Late?,  in Hospital of Salerno	Our study aims to compare the effect of hyperbaric oxygen therapy (HBOT), oral steroids (OS) and combination of both therapies (HBOT + OS) for treating SSNHL	<b>Design:</b> Randomized study analyzed <b>Analysis:</b> Statistical analysis using one-way ANOVA and Chi-square methods <b>Sample:</b> Data collected from 171 patients experiencing sudden deafness <b>Instrument:</b> Divided into 3 treatment groups. Group A received hyperbaric oxygen therapy only (N=60) with an average age of 55.7, consisting of 31 male and 29 female patients; Group B received oral steroid therapy only (N=55) with an average age of 67.7, comprising 29 male and 26 female patients; Group C received both hyperbaric oxygen therapy and oral steroid therapy (N=56) with an average age of 44.1, consisting of 31 male and 25 female patients	The research findings indicate that the combination of hyperbaric oxygen therapy with oral steroids shows a significantly better improvement than the group receiving hyperbaric oxygen therapy alone (p<0.05). Both the hyperbaric oxygen therapy group and the combination group of hyperbaric oxygen therapy and oral steroids show significant variations before and after treatment, respectively (p<0.05). In audiometric examinations, patients with severe deafness during the recovery process show no significant difference between using hyperbaric oxygen therapy alone (9.3), steroids alone (8.3), and the combination therapy of hyperbaric oxygen + oral steroids (13.9) with (p=0.08). Meanwhile, upsloping hearing thresholds show favorable

No	Author, Year Title, Location	Purpose	Method	Result
				results with the use of hyperbaric oxygen therapy alone (14.8) compared to oral steroids alone (0) and the combination therapy of hyperbaric oxygen and oral steroids (13.9) with ( $p<0.05$ ). For downsloping and flat hearing thresholds, a combination of hyperbaric oxygen therapy and oral steroids (33.3/38.9) yields better results compared to hyperbaric oxygen therapy alone (31.5/44.4) with ( $p<0.05$ ).
11	Yücel A, Özbuğday Y. (2020)  Comparison of Steroid Treatment with and without Hyperbaric Oxygen Therapy for Idiopathic Sudden.  at the author's clinic.	The aim of the study is to compare the outcomes of patients with idiopathic sudden sensorineural hearing loss who underwent steroid treatment with or without hyperbaric oxygen (HBO) therapy and were monitored.	<b>Design:</b> Retrospective cohort <b>Analysis:</b> Descriptive statistical analysis method with normality tests, Kolmogorov-Smirnov and Shapiro-Wilk tests. Comparison of numerical data between groups and variables using independent simple t-test, chi-square, and Fisher tests. <b>Sample:</b> A total of 272 patients with sudden deafness . Instrument: Group 1, consisting of 194 patients receiving steroids + hyperbaric oxygen therapy, with an average age of 48-46 years, and a female-to-male ratio of 83/111. Group 2, comprising 78 patients receiving steroids, with an average age of 48-46 years, and a female-to-male ratio of 31/47. <b>Treatment procedure :</b> Patients were divided into two groups based on the treatment regimen. The first group (Steroid group) received IV methylprednisolone at 1 mg/kg, to be completed over 2-3 weeks with decreasing doses, and five doses of 0.5 mL intratympanic dexamethasone. The second group (Steroid+HBO group) received the same steroid treatment along with hyperbaric oxygen therapy (HBO). Each HBO therapy session was conducted at 2 atmospheres absolute (ATA) for 1 hour, totaling 20 sessions daily, excluding weekends. Intratympanic and IV steroid treatment commenced simultaneously in both patient groups.	The research findings indicate no significant differences between the two groups in terms of average age and gender ( $p<0.05$ ). The PTA levels before and after treatment were 65 and 43 dB, respectively, for each group. There were no significant differences in the pre-treatment PTA values and hearing threshold improvement for each group ( $p>0.05$ ).

## DISCUSSION

### Vascular Endothelium in Sudden Deafness

Sudden deafness is a case that requires immediate intervention. The percentage of patients suffering from Sudden deafness and not receiving proper treatment ranges from 28 to 65%, with symptoms appearing within two weeks. Ignoring Sudden deafness can lead to permanent hearing loss. So far, there is no exact theory from researchers regarding the causes of sudden hearing loss. According to McTaggart et al in 2018, it is explained that 1% of Sudden deafness cases are caused by retrocochlear disorders related to vestibular schwannoma, demyelinating diseases, or stroke. Meanwhile, 10-15% of other cases are caused by Meniere's disease, trauma, autoimmune diseases, syphilis, Lyme disease, or perilymphatic fistula. One systematic review outlines several possible causes of sudden hearing loss, including idiopathic (71%), infectious diseases (12.8%), ear diseases (4.7%), trauma (4.2%), vascular and hematologic (2.8%), neoplasms (2.3%), and other causes (2.2%).<sup>14</sup>

One cause of Sudden deafness is injury to the vascular endothelium of the labyrinthine arteries. This occurs due to very loud noises causing trauma to the hearing. Because of the injury, bleeding will occur, which will quickly move towards the wound, causing tissue hypoperfusion, resulting in inflammation or non-inflammatory reactions. This inflammatory process is a reaction of the body's immune system to protect the surrounding tissue, causing tissue hypoperfusion, increased plasma, and blood viscosity due to injury or trauma. The impact will affect tissues such as tissue hypoxia, necrosis, and cell death. In the case of hearing, this vascular hypoperfusion condition will lead to the loss of function of the organ of Corti, resulting in sudden hearing loss.

According to research by Thompson et al in 2020<sup>15</sup>, an acute response that can be identified as Sudden deafness can occur for 48-72 hours after the onset of sudden hearing loss. Comparing the neutrophil/lymphocyte ratio decreases for the causes of Sudden deafness due to viral infections, while the neutrophil/lymphocyte ratio increases for the causes of vascular disorders. Inner ear damage causes an increase in glutamate secretion at synapses between inner hair cells and neurons. This results in disrupted mechano-electrical transduction, leading to changes in acoustic stimulation into nerve impulses. Consequently, a decrease in hearing ability occurs. Persistent hair cell dysfunction plays a role in increasing glutamate proportionally with an increase in cytoplasmic and intramitochondrial calcium in afferent nerves. This leads to mitochondrial depolarization, ultimately resulting in apoptosis.<sup>16</sup>

The diagnosis of Sudden deafness according to the Guideline of the American Academy of Otolaryngology-Head and Neck Surgery requires differentiation between sensorineural hearing loss and conductive hearing loss. This can be done through audiometric examination, physical examination, medical history, tuning tests, and other supporting tests<sup>2</sup>. The difference between these two types of hearing loss is that conductive hearing loss is caused by abnormalities in the outer ear, middle ear air cavity, bone structure, abnormalities in the outer ear, and hearing bones. Meanwhile, sensorineural hearing loss is caused by abnormalities in the cochlea, auditory nerve, and other parts involved in processing neural impulses to the auditory cortex of the brain.<sup>17</sup>

In a research journal by Chrisna et al in 2021, it is stated that the most common onset of Sudden deafness is <7 days, accounting for 80.6% of patients. Symptoms of Sudden deafness

that may occur include a sudden loss of hearing ability of 30 dB at three consecutive frequencies within 72 hours. Patients will experience symptoms in the morning, with a decline in hearing ability. These symptoms are nonspecific, leading to delays in diagnosis and treatment. Other symptoms that may be found include a full sensation in the ear, vertigo, otorrhea, tinnitus, disequilibrium, headache, otalgia, and others. Audiometric examination should be done immediately, within a maximum of 14 days after symptoms appear, to diagnose sudden hearing loss.<sup>18</sup>

### **Characteristics of Sudden Deafness Sufferers**

The highest characteristics of patients with sudden deafness who were treated with a combination of hyperbaric therapy were men. There are nine references that support the provision of hyperbaric combination therapy for sudden deafness according to gender.

In various studies, there are variations in the number of samples of patients with sudden deafness.<sup>18</sup> reported the results of research with 36 samples,<sup>19</sup> with 115 samples, and<sup>20</sup> with 83 patients, showed differences in the gender distribution of sufferers, where in some studies the number of women was greater than men.

A risk factor that contributes to the high incidence of sudden deafness in men is smoking<sup>18</sup>. it increases the risk of sudden deafness in several ways. Exposure to cigarette smoke can damage blood vessels in the ear, including the labyrinthine artery, which can disrupt blood flow to the ear over the long term. Additionally, the toxic substances in cigarettes can damage nerve tissue in the inner ear, contributing to hearing loss. Research also indicates that smoking can increase the risk of vascular diseases, including heart disease and stroke, which can also

negatively impact hearing. Therefore, the habit of smoking can increase the likelihood of experiencing sudden deafness. The combination of hyperbaric oxygen therapy with steroids is more effective in improving sudden deafness in women, which is attributed to differences in cardiovascular anatomy<sup>21</sup>. There are also differences in therapy results between age groups, where hyperbaric oxygen therapy with steroids provides better results in patients under 50 years of age.<sup>22</sup>

Age is the main risk factor for sudden deafness, with deafness increasing with age. natural aging processes occur that can lead to changes in the auditory organs. These include decreased vascular function in the ear, damage to the auditory nerves, and alterations in the inner ear structure. All of these factors can increase the risk of sudden hearing loss as one gets older. Internal factors such as genetics and external factors such as exposure to loud noise also play a role in deafness. Research by<sup>18</sup> showed that sudden deafness tended to be higher at ages under 50 years, and the prevalence was highest at ages 41-50 years.<sup>22</sup> Hyperbaric oxygen therapy (HBOT) is likely more effective in patients under 50 years of age due to several reasons. Firstly, younger individuals generally have better regenerative capabilities compared to older individuals. Therefore, in the case of HBOT, where increased oxygen supply can aid in tissue repair, younger patients may respond more positively to this treatment. Additionally, younger individuals are less likely to have comorbidities or other factors that may limit the effectiveness of therapy, thus making HBOT more effective in this age group.<sup>23</sup>

Underlying disease factors such as diabetes mellitus and hypertension are correlated with vascular abnormalities that can cause sudden deafness. Research by Hosokawa et al (2018)

showed that hyperbaric oxygen therapy with steroids provided significant hearing improvements in patients with diabetes mellitus and hypertension. This shows that the underlying disease condition can influence the results of therapy in sufferers of sudden deafness.<sup>24</sup>

### **Hyperbaric Oxygen Therapy as an Adjuvant Therapy for Sudden Deafness**

The mechanism of hyperbaric oxygen therapy operates based on Henry's law, which states that the amount of gas dissolved in a fluid or tissue is proportional to the partial pressure of the gas in contact with the fluid or tissue. In hyperbaric oxygen therapy, the supplied oxygen increases, thus raising its pressure within the tissues and resulting in hyperoxia effects on hypoxic tissues.<sup>25</sup>

When oxygen pressure decreases, neutrophils become active. These neutrophils consume oxygen, leading to decreased oxygen levels in hypoxic tissues. Low oxygen levels cause tissue injury. This is the role of hyperbaric oxygen therapy, which restores hypoxic tissue injury by increasing oxygen concentration. Neutrophils then supply oxygen, initiating the healing process. High oxygen levels induce changes in tissues beneficial for post-traumatic tissue edema. Neovascularization is influenced by oxygen concentration, with higher oxygen pressure leading to increased capillary growth.<sup>26</sup>

From the research conducted by Dewi and Savitri (2021) the administration of hyperbaric oxygen therapy to 36 patients at Dr. Mintohardjo Naval Hospital for 90 minutes once daily for 10 days at a pressure of 243 kPa resulted in hearing improvement in 31 patients. Additionally, it was found that the degree of hearing impairment and the onset of sudden hearing loss were not significantly associated with hearing improvement.<sup>18</sup>

Another study conducted by Tong et al. in 2021 on 136 patients divided into two groups, namely the first group receiving pharmacological therapy and the second group receiving a combination of pharmacological therapy and hyperbaric oxygen therapy. It was found that the success rate of the pharmacological therapy and hyperbaric oxygen therapy group was 60.6%, while the group receiving only pharmacological therapy was 42.9%. The pharmacological therapy and hyperbaric oxygen therapy group had a higher success rate compared to the group receiving only pharmacological therapy ( $p < 0.05$ ).<sup>22</sup>

Another study by Hosokawa et al. in 2018 found that among 356 patients with sudden hearing loss in the hyperbaric oxygen therapy (HBOT) + systemic steroid (SS) group, 42 out of 161 (26.1%) patients showed total recovery, 41 (25.5%) showed good recovery, 42 (26.1%) showed fair recovery, and 36 (22.4%) showed no change. The overall hearing recovery rate was significantly higher in the hyperbaric oxygen therapy (HBOT) + systemic steroid (SS) group (125/161 [78.3%]) compared to systemic steroid (SS) alone (52/160 [32.5%];  $p < 0.001$ ) and intratympanic injection (IT) + systemic steroid (SS) (17/35 [48.6%];  $p < 0.001$ ). Improvement based on hearing grade level with hyperbaric oxygen therapy + systemic steroid was as follows: grade 1 (<40dB) 62.5%, grade 2 (40-60dB) 65.5%, grade 3 (60-90dB) 84%, grade 4 (>90dB) 77.6%. Improvement based on hearing grade level with systemic steroid was as follows: grade 1 (<40dB) 25.5%, grade 2 (40-60dB) 60%, grade 3 (60-90dB) 30.8%, grade 4 (>90dB) 76.2%.<sup>24</sup>

There is an influence of other variables including the mean level of hearing at 5 initial frequencies. The control group received intratympanic steroid therapy, and the group given additional hyperbaric oxygen therapy for 14 days, with a frequency of once a day.

After two weeks of treatment, there was a significant increase in hearing frequency ( $p = <0.05$ ) in the group receiving hyperbaric oxygen therapy and steroids ( $28.1 \pm 26.9$  dB) compared to the control group ( $14.8 \pm 13.5$  dB). Hyperbaric oxygen therapy has shown to be effective as an initial treatment option for patients experiencing idiopathic sudden sensorineural hearing loss.<sup>20</sup>

From the study conducted by Cavaliere et al. in 2022, it was found that the combination of hyperbaric oxygen therapy with oral steroids showed significantly better improvement than the group receiving hyperbaric oxygen therapy alone ( $p < 0.05$ ) and oral steroids alone ( $p < 0.05$ ). Patients undergoing hyperbaric oxygen therapy achieved better recovery compared to those treated with oral steroids alone ( $p < 0.05$ ). Both the hyperbaric oxygen therapy group and the combination group showed significant variations before and after treatment for each group ( $p < 0.05$ ). In audiometric examination, patients with severe hearing thresholds during the recovery process showed no significant difference between using hyperbaric oxygen therapy alone (9.3), steroids alone (8.3), and the combination therapy of hyperbaric oxygen + oral steroids (13.9) with ( $p = 0.08$ ). However, upsloping hearing thresholds showed better results with hyperbaric oxygen therapy alone (14.8) compared to oral steroids alone and the combination therapy of hyperbaric oxygen and oral steroids (13.9) with ( $p < 0.05$ ). For downsloping and flat hearing thresholds, the combination therapy of hyperbaric oxygen and oral steroids (33.3/38.9) showed better results compared to hyperbaric oxygen therapy alone (31.5/44.4) with ( $p < 0.05$ ).<sup>21</sup>

From the study by Yücel A, & Özbuğday Y in 2020, the research results showed no significant difference between the two groups in terms of

mean age and gender ( $p < 0.05$ ). The PTA (pure-tone average) levels before and after treatment were 65 and 43 dB for each group. There was no significant difference in PTA values before treatment and the increase in hearing threshold for each group ( $p > 0.05$ ).<sup>27</sup>

Another study conducted by Anh et al. in 2021 showed findings from 3 treatment groups treated with oral steroids (PO), oral steroids and intratympanic injections (PO+IT), a combination of hyperbaric oxygen therapy, oral steroids, and intratympanic injections (IT+PO+HBOT). Patients given the combination therapy (IT+PO+HBOT) for hearing impairment  $> 80$  dB showed low hearing recovery values in the HBOT group ( $P = 0.076$ ). The results of statistical analysis between groups for each PTA frequency did not yield significant results.<sup>28</sup>

Research results by Eski et al. in 2020 on 136 patients with sudden hearing loss obtained from hospital medical records. 33 patients received hyperbaric oxygen therapy (HBOT) and 36 patients received intratympanic steroid injections (ITS) after systemic steroids (SST). The results showed a higher recovery time with ITS (40%) compared to HBOT (17%). This study indicates differences before and after ITS treatment ( $p < 0.05$ ). The recovery time was higher in the ITS treatment group compared to the HBOT group.<sup>29</sup>

The results of the above 5 studies indicate that hyperbaric oxygen therapy alone or combined with medicinal therapy (systemic steroids, intratympanic steroids), or pharmacological therapy alone, yield better outcomes in hearing improvement compared to pharmacological therapy alone. Three research journals state that the combination of hyperbaric oxygen therapy with medicinal therapy is ineffective.

The effectiveness of hyperbaric oxygen therapy in healing is influenced by pressure. From these research

findings, it can be understood that to increase the effectiveness of hyperbaric oxygen therapy, pressure usage is crucial. This aligns with the principle that higher pressure correlates with gas solubility. The higher the pressure given up to 3 ATA, the higher the oxygen diffusion capacity increases to 4 times higher than at 1 ATA pressure, thus potentially saving tissue to remain alive.<sup>30</sup>

The administration of hyperbaric oxygen therapy using pressures ranging from 1.5 to 3 ATA for a duration of 60 to 120 minutes once or twice daily resulted in improvement in 81% of cases of sudden hearing loss, with hearing improvement ranging from 0 to 60 dB with an average of 20 dB. Another study mentioned that the administration of 1.8 ATA pressure was significantly higher than the 2.2 ATA group ( $p < 0.05$ ). This indicates that hyperbaric oxygen therapy at 1.8 ATA pressure has a more significant therapeutic effect on sudden hearing loss, which can improve inner ear circulation, increase oxygen supply, and restore patient hearing levels with ideal effects.<sup>31</sup>

A similar study by Krajčovičová et al. in 2019 using pressures of 2.0 ATM and 2.5 ATM found that hyperbaric oxygen therapy at 2.5 ATM pressure was more efficient at low frequencies, while better hearing was obtained at 2 ATM pressure for high frequencies.<sup>19</sup>

In conclusion, for hyperbaric oxygen therapy to be effective in treating sudden hearing loss, the pressure in the hyperbaric chamber during hyperbaric oxygen therapy should be at least 1.5 – 1.8 ATA, thus contributing to a significant increase in the oxygen diffusion radius from capillaries to surrounding tissues. Research indicates that increasing the maximum pressure during hyperbaric oxygen therapy beyond 2.5 ATA does not provide any benefit for hearing recovery; therefore, air pressure at 2.0 to 2.5 ATA can be

recommended for the treatment of sudden deafness.<sup>32</sup>

Other studies indicate the influence of the number of therapy sessions provided to patients with sudden hearing loss. A study by Chin, Lee, Chen, & Wu,(2022) stated that hyperbaric oxygen therapy divided into two groups, with the first group receiving therapy for 1 to 5 sessions involving 102 patients and the second group receiving therapy for 6 to 10 sessions involving 46 patients. Furthermore, the research results indicate that in patients given hyperbaric oxygen therapy for 1-5 sessions, 45 out of 102 patients (44.1%) showed improved hearing improvement ( $p < 0.000$ ). Meanwhile, hyperbaric oxygen therapy after 6-10 sessions did not show significant improvement.<sup>31</sup>

Based on the research conducted and various results obtained, administering hyperbaric oxygen therapy as early as possible will improve clinical improvement outcomes. Various evidence from the research review indicates good results when hyperbaric oxygen therapy is given within 2 weeks of the onset of hearing loss, including in patients showing clinical improvement from severe sudden hearing loss to moderate hearing loss.<sup>20</sup> Hyperbaric oxygen therapy given more than 2 months since the onset of hearing loss makes recovery difficult and slow.<sup>31</sup>

Hyperbaric oxygen therapy is intended to improve microvascularization within the cochlea. Adequate oxygenation will nourish sensory elements and nerves in the cochlea, increase cell metabolism, and activate the Na<sup>+</sup> K<sup>+</sup> pump, thereby promoting the restoration of homeostasis in cochlear electrophysiological function. The use of hyperbaric oxygen therapy has also been clinically proven to be effective when combined with primary corticosteroid-based therapy, especially in patients with sudden hearing loss of high severity.<sup>9</sup>

## CONCLUSION

The conclusions that can be written in this research are patients who experience abrupt hearing misfortune having qualities in light of orientation, the greater part of them are men, in view old enough, it frequently happens in productive age (<50 years) and is influenced by causal factors such as diabetes mellitus and hypertension. Hyperbaric oxygen therapy in combination affects improving sudden deafness. The author's recommendation is for further research to explore various factors affecting the effectiveness of hyperbaric oxygen therapy in improving sudden hearing loss and that hyperbaric oxygen therapy could be one of the adjunctive therapies provided to patients in Indonesia.

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