

Tinnitus evolution in patients with sudden sensorineural hearing loss treated with hyperbaric oxygen therapy

Original Article

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Abstract

Introduction: Sudden sensorineural hearing loss presents with tinnitus in up to 90% of cases. Tinnitus constitutes a subjective complaint, therefore hard to quantify and evaluate. Hyperbaric oxygen therapy (HOT) constitutes a valuable adjunctive therapy in patients who are only partially responsive or refractory to corticoid treatment, but the effect it may have on tinnitus remains poorly studied.

Goals: To evaluate HOT effect on tinnitus and audiometric evolution in sudden sensorineural hearing loss with tinnitus, refractory to corticoid treatment.

Methods: This paper presents a prospective non-controlled study that applied Tinnitus Handicap Inventory (THI) before and after treatment with HOT. The study was carried in the Portuguese Navy's Center for Hyperbaric and Subaquatic Medicine, between May and December, 2018. The Center's HOT protocol included on average 20 sessions at 2.5 ATM for 90 minutes. The statistic analysis was performed using IBM SPSS Statistics 26 software.

Results: 57 patients were included in the study, with ages between 25-78 years (average 51), 50.8% female. The average time between symptom onset and HOT was 34,9 days. We were able to make an inverse correlation between the symptom-treatment window and hearing outcomes ($p=0,045$). The average hearing outcome was of 17dB. According to Spiegel's hearing outcome classification, there was complete recovery in 19% of patients, partial recovery in 23%, slight improvement in 33% and no improvement in 25% of patients. Regarding tinnitus, most patients had a THI classification of grade 3 or 4 before treatment (71%). After treatment, 77% of patients presented a THI score <3 . We observed an improvement of THI classification even in patients with no audiometric improvement.

Conclusion: This data concludes that, besides improving hearing outcomes, HOT seems to have a positive effect in improving tinnitus and its impact in the patient's quality of life. Patients should be referred to HOT treatment as soon as possible, since the window between symptom

onset and HOT treatment has a significant effect on hearing outcomes.

Keywords: Sudden deafness; tinnitus; hyperbaric oxygen therapy; sensorineural hearing loss

Introduction

Sudden sensorineural hearing loss (SSNHL) is defined as a loss of hearing of at least 30 dB in three consecutive audiometric frequencies occurring within at least 72 hours^{1,2}. Its incidence is estimated between five and 30 cases/100,000/year³. Although it affects individuals of all ages, the peak incidence is between the fifth and sixth decades of life, and it occurs with equal frequency in men and women^{2,4,5}. Between 2% and 5% of patients exhibit bilateral involvement, which is typically sequential². The accompanying symptoms include tinnitus (80-90%), vertigo (29-56%)^{2,4,6,7}, and ear fullness. When the symptoms are severe, they may be associated with anxiety, depression, and sleep disturbances^{9,10}.

The etiology of SSNHL is only identified in 10% of patients¹¹, with the remaining cases being denominated as “idiopathic” (ISSNHL)^{2,4,12}. The differential diagnosis includes infectious, traumatic, vascular, neoplastic, autoimmune, metabolic, and neurological causes^{2,3}. In most cases in which it is possible to determine the etiology, hypoacusis results from irreversible damage to the cilia². In response to an incongruent auditory message, the cortical auditory centers adapt and remodel the transmitted signal, and this neuroplasticity can lead to the perception of unreal sounds (tinnitus)¹³. Most patients with ISSNHL spontaneously recover some degree of their hearing (32%-65%) in the first two weeks⁴. When the condition lasts longer than two to three months, the hearing loss will probably become permanent^{2,4}. Some prognostic factors include age, degree of hypoacusis, affected frequencies, presence of vertigo, and time window between the onset of symptoms and the start of treatment^{2,3}. Several treatments have been proposed and used for this disease, including vasodilators, plasma expanders,

corticosteroids, anticoagulants, diuretics, and antivirals. Currently, systemic or intratympanic corticosteroid therapy appears to be the most recommended treatment^{2,3,9}, as it reduces inflammation and edema in the inner ear.

Hyperbaric oxygen therapy (HOT) is a coadjuvant treatment that entails the administration of 100% oxygen at a pressure greater than 1ATM. Despite its widespread use, the results are controversial¹⁴⁻¹⁶, partly because of the high variability of the clinical criteria and protocols that are used. HOT increases the partial pressure and concentration of oxygen in the inner ear, thereby improving microvascularization and reducing the associated edema^{9,17}. HOT appears to improve hypoacusis after ISSNHL, but there is very little evidence about its benefit regarding the associated tinnitus¹⁶. The reduced quality of life of patients with SSNHL appears to be more related to the intensity of tinnitus than to the hearing loss itself¹⁸. Therefore, it is important to determine the effect of HOT on SSNHL-associated tinnitus, in addition to its impact on auditory acuity per se.

The objective of this study was to assess the effect of HOT on the progression of tinnitus and auditory thresholds in patients with SSNHL-associated tinnitus, in whom treatment with systemic or transtympanic corticosteroid therapy did not lead to a significant symptom improvement.

Methods

This was a prospective non-controlled study conducted between May and December 2018 at the Center for Underwater and Hyperbaric Medicine of the Portuguese Navy in patients diagnosed with sudden hearing loss refractory to treatment with systemic and/or transtympanic corticosteroid therapy, who were referred to the Center. All patients were over 18 years old at the time of the study and signed an informed consent form.

The criterion for treatment (and, therefore, inclusion in the study) has been defined as the presence of hypoacusis of 30 dB or more in at least three contiguous frequencies occurring

Table 1
Tinnitus Handicap Inventory^{20,21}

Degree of severity of tinnitus	Characterization
Grade 1 (0-16) – Very mild	Is perceived only in silence. Without evident disturbances.
Grade 2 (18-36) – Mild	Easily masked by environmental sounds and forgotten during daily activities. It may occasionally interfere with sleep.
Grade 3 (38-56) – Moderate	Perceived even in environments with some sound. Daily activities are not impaired; interferes with sleep and with silent activities.
Grade 4 (58-76) – Severe	Interferes with almost all daily activities, especially with those carried out in silent environments.
Grade 5 (78-100) – Catastrophic	All symptoms associated with tinnitus are present and the associated psychopathology is eventually present.

within less than 72 h. In the absence of a pure-tone audiogram performed before the hearing loss or history of asymmetric hypoacusis, the pure tone average (PTA – mean of the auditory thresholds in the 500, 1k, 2k, and 4k frequencies) of the contralateral ear has been defined as the baseline value. PTA has been quantified as 110 dB in the case of cophosis.

The HOT protocol included a mean of 20 sessions at 2.5 ATM for 90 minutes. After 10 treatment sessions, clinical evaluation and audiometry tests were performed.

All patients who had not completed the number of treatments proposed by the physician (due to complications or patient drop out) were excluded.

The Tinnitus Handicap Inventory (THI) was used for the qualitative evaluation of tinnitus and its impact on the patient's quality of life, before and after treatment with HOT (questionnaire for the qualitative evaluation of the impact of tinnitus on the patient's quality of life). All patients underwent audiometry and tympanometry tests before

and after completing the proposed number of treatments. Auditory acuity improvement was classified according to Siegel's classification criteria¹⁹. The created database included demographic and clinical data (sex, age, unilaterality/bilaterality, and affected ear), the interval of time between the onset of symptoms and the start of HOT, initial and final PTA, and initial and final THI scores.

The statistical analysis was performed using the IBM SPSS Statistics 26 software. The statistical significance level was set at $p < 0.05$. Pearson's and Student's t-test were used for correlation analysis.

Results

Of the 57 patients included in the study, 52 (91%) had unilateral sudden hearing loss and five (8.8%) had bilateral hearing loss. The participants' age varied between 25 and 78 years (mean of 51 years); 50.8% of the patients were women and 49.2% were men.

The interval of time between the onset of symptoms and start of HOT was 7 to 103 days

Table 2
Siegel's Classification Criteria

Siegel's Classification Criteria ¹⁹	
Complete recovery	Final PTA <25 dB
Partial recovery	PTA gain >15 dB and final PTA between 25 and 45 dB
Slight recovery	PTA gain >15 dB and final PTA >45 dB
No improvement	PTA gain <15 dB

Abbreviation: PTA, pure tone average

(mean of 34.9 days). The inverse relationship between the time window between the onset of symptoms and HOT (symptom-treatment interval) and auditory acuity improvement was statistically significant ($p=0.045$). Moreover, an inverse relationship between the symptom-treatment interval and THI improvement was observed, but the result was not statistically significant ($p=0.08$). The auditory gain was positively correlated with the improvement in tinnitus, although the result was not statistically significant ($p=0.06$). An inverse relationship between patient age and auditory gain with improvement in

tinnitus was observed, but the result was not statistically significant ($p=0.256$ for auditory gain and $p=0.193$ for THI improvement). The obtained PTA recoveries (mean of the auditory thresholds 500, 1k, 2k, and 4k) were between 0 and 63 dB, with a mean gain of 17 dB (mean of the PTA gain among all patients included in the study). According to Siegel's criteria of auditory recovery, there was complete recovery in 19% of patients, partial recovery in 23%, slight improvement in 33%, and no improvement in 25%. The severity of the initial hearing loss was not related to the improvement in the auditory thresholds.

Figure 1
Unilateral vs bilateral sudden hearing loss

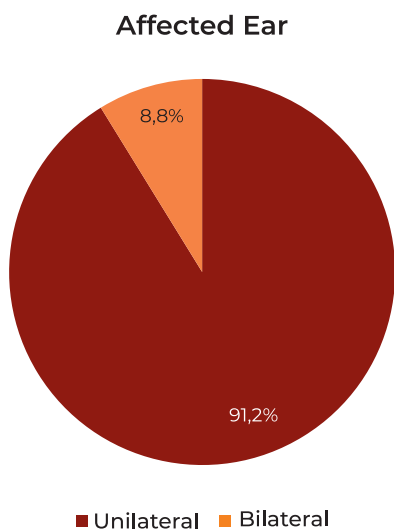


Figure 2
Distribution according to sex

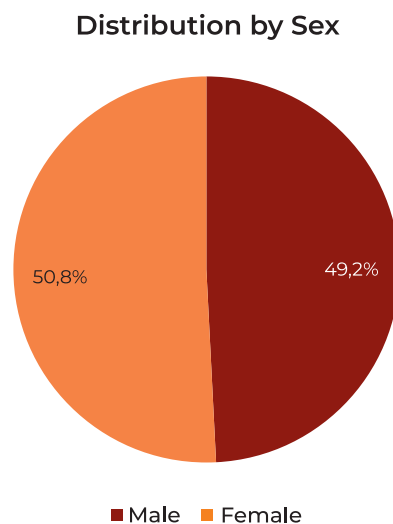


Figure 3
Distribution of Patients According to Age

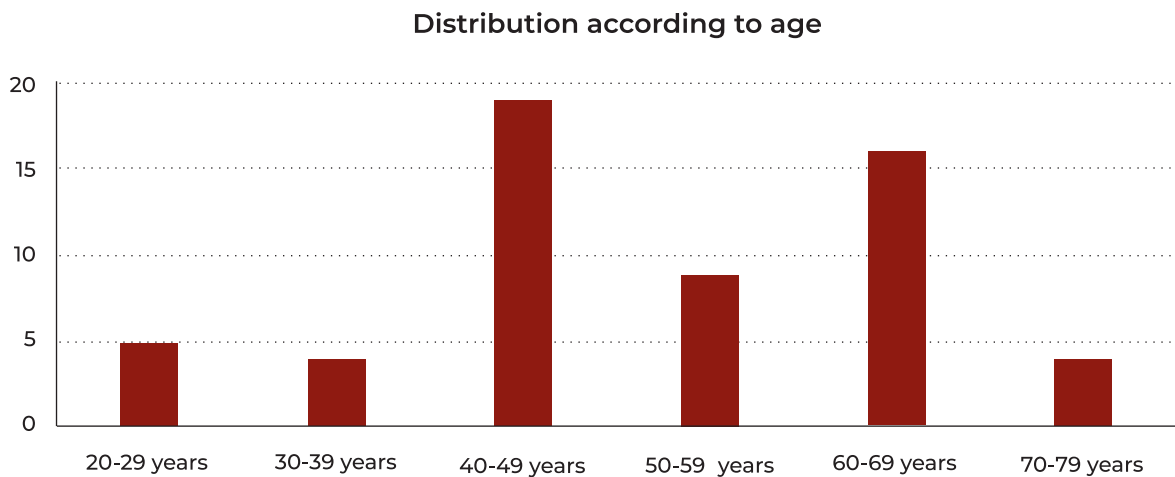


Table 3

Statistical relationship between auditory gain, improvement in tinnitus, and interval between the onset of symptoms and HOT treatments

		Auditory gain	THI improvement	No. of days between symptom onset and start of HOT
Auditory gain	Pearson's correlation	1	0,064	-0,267*
	Significance (p)	-	0,638	0,045
THI improvement	Pearson's correlation	0,064	1	-0,086
	Significance (p)	0,638	-	0,527
No. of days between symptom onset and start of HOT	Pearson's correlation	-0,267*	-0,086	1
	Significance (p)	0,045	0,527	-

* The correlation is significant at 0.05 (two ends).

Abbreviations: HOT, Hyperbaric oxygen therapy, THI, Tinnitus Handicap Inventory

Table 4

Statistical relationship between age, auditory gain, and tinnitus improvement

		Auditory gain	THI improvement	Age
Auditory gain	Pearson's correlation	1	0,064	-0,256
	Significance (p)	-	0,638	0,054
THI improvement	Pearson's correlation	0,064	1	-0,193
	Significance (p)	0,638	-	0,150
Age	Pearson's correlation	-0,256	-0,193	1
	Significance (p)	0,054	0,150	-

Abbreviations: THI, Tinnitus Handicap Inventory

The mean THI score before treatment with HOT was 3.1 (perceived even in the presence of sound) and 1.98 after HOT (easily masked and forgotten). The most significant gain was observed in patients with grade 3 and grade 4 tinnitus. It was not possible to establish a statistically significant relationship between the degree of tinnitus and the degree of hearing loss before and after treatment.

There was an improvement in the severity of tinnitus even in patients without audiometric improvement according to Siegel's criteria.

Discussion

There was a significant improvement in the THI score with regard to tinnitus severity, especially in patients with complete auditory recovery, although without statistical

Table 5

Audiometric improvement according to the initial PTA

Initial PTA (dB)	Mean PTA gain (dB)	Number of patients	No. of days symptoms-HOT (mean)
20-40 (Mild hypoacusis)	11,93	14	41,36
40-70 (Moderate hypoacusis)	17,40	21	39,76
70-90 (Severe hypoacusis)	14,75	15	31,2
90-110 (Profound hypoacusis)	24,28	7	32,39

Abbreviations: HOT, Hyperbaric oxygen therapy, PTA, pure tone average

Figure 6
Audiometric improvement according to Siegel's criteria

Audiometric Improvement According to Siegel's Criteria

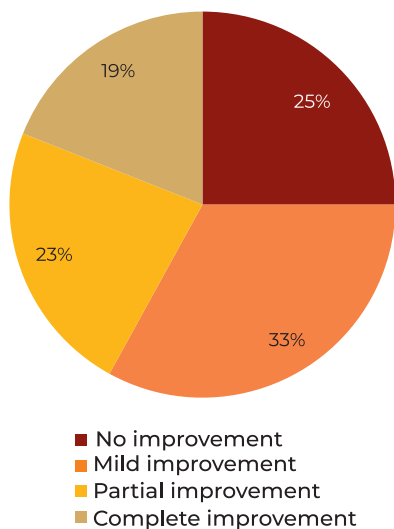


Table 6
THI score before and after HOT

THI Score	Pre-HOT	Post-HOT
Grade 1 – Very mild	10%	40%
Grade 2 – Mild	12%	37%
Grade 3 – Moderate	39%	12%
Grade 4 – Severe	32%	5%
Grade 5 - Catastrophic	7%	5%

Abbreviations: HOT, Hyperbaric oxygen therapy, THI, Tinnitus Handicap Inventory

significance ($p=0.206$). In general, tinnitus improved regardless of the auditory gain. These results are in line with those of some previous studies that indicated that HOT has a significant role in the improvement of tinnitus associated with SSNHL^{14,16,22}. However, based on the natural history of SSNHL, it rarely shows spontaneous recovery after 14 days of progression^{12,15,23}, and a significant spontaneous improvement in tinnitus and PTA is therefore unlikely in this interval of time (considering that all the included cases were refractory to previous corticosteroid therapy). Further studies are necessary to assess the natural course of tinnitus in patients with sudden hearing loss and to evaluate the spontaneous improvement in tinnitus over time, in particular in patients with no auditory gain. In the most recent meta-analysis on this topic, which was published in January 2022¹⁵, it was concluded that HOT, combined with corticosteroid therapy, increased auditory gain by approximately 15 dB, which was the most significant at frequencies of 250, 500, 1000, and 4000 and in patients aged less than 50 years². The mean improvement in auditory acuity was 17 dB, which is within the intervals described in the literature (12.9-50 dB^{2,22}). There is a trend in the literature to consider that the patients with a greater initial hearing loss (higher PTA) have a worse prognosis and are less likely to recover spontaneously in audiometric terms^{2,15,22}. In the present study, the patients with initial PTA

Figure 7
Improvement in Tinnitus (mean THI score) according to the Auditory Gain. THI, Tinnitus Handicap Inventory

Improvement in Tinnitus according to the Auditory Gain

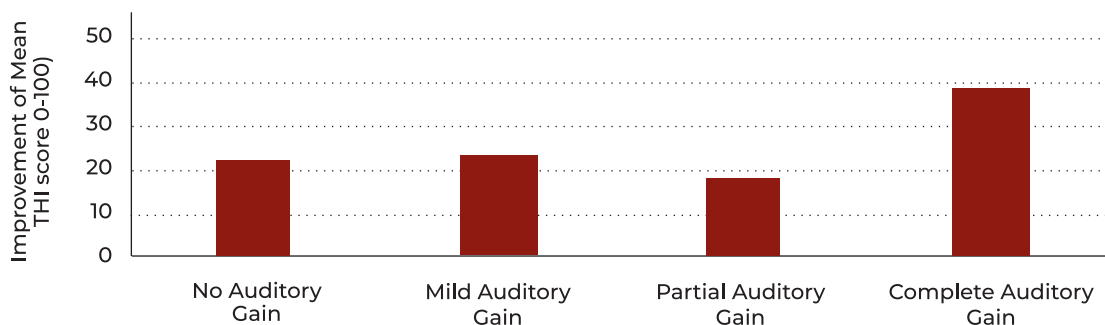
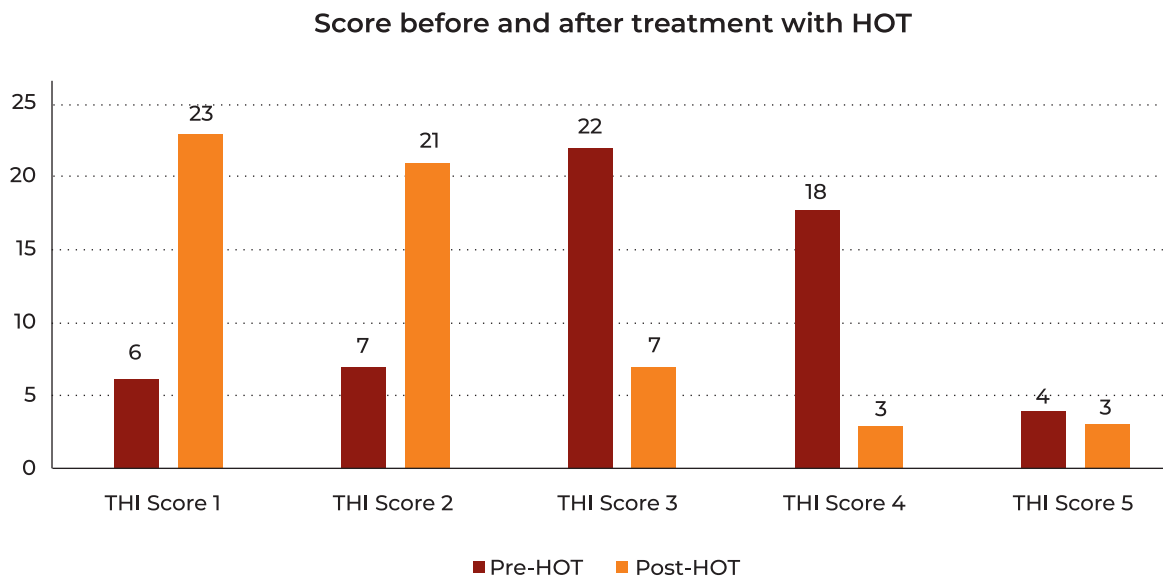


Figure 8

THI score before and after treatment with HOT. THI, Tinnitus Handicap Inventory; HOT, Hyperbaric oxygen therapy.



>90 dB demonstrated a mean improvement of approximately 24 dB, which corresponds to a slight improvement according to Siegel's criteria but in quantitative terms, corresponds to a better recovery than that in patients with a lower initial PTA. The patients with a more severe hearing loss had a worse initial prognosis and for this reason, tended to be referred earlier for HOT (see Table 5), which may translate into a selection bias (they may have recovered better because they were referred earlier).

The incidence of bilateral SSNHL in the present study was 8.8%, which is approximately two to four times higher than that reported in previous studies (2%-5%)². This may be because these patients were specifically referred to our center after the failure of corticosteroid therapy and that bilateral SSNHL is a factor for worse prognosis for spontaneous recovery or improvement with the use of corticosteroids². Thus, this increase is more likely due to a selection bias than to an increased incidence of bilateral SSNHL in the Portuguese population. The interval of time between the onset of symptoms and the start of HOT was seven to 103 days (mean of 34.9 days), which is markedly longer than that in other published studies (mean interval of

11.2-17 days^{14,16}). The time interval between the onset of symptoms and the start of HOT was the most important determining factor for auditory acuity improvement, which is in line with previous reports^{9,17}.

The main limitation of this study was that it did not include a control group, which would allow the establishment of a more robust causal relationship between the improvement in tinnitus and treatment. Further studies are therefore necessary.

Conclusion

HOT appears to improve tinnitus and therefore has an impact on the quality of life of these patients, even when the auditory gain is not significant. In addition, it leads to an improvement in auditory acuity in patients with SSNHL refractory to corticosteroid therapy, with the results being more significant in cases where the interval between the onset of symptoms and initiation of treatment is shorter.

Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Data Confidentiality

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

Protection of humans and animals

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the 2013 Helsinki Declaration of the World Medical Association.

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Availability of scientific data

There are no datasets available, publicly related to this work.

Bibliographic references

- Schreiber BE, Agrup C, Haskard DO, Luxon LM. Sudden sensorineural hearing loss. *Lancet* 2010 Apr 3;375(9721):1203-11. doi: 10.1016/S0140-6736(09)62071-7.
- Kuhn M, Heman-Ackah SE, Shaikh JA, Roehm PC. Sudden Sensorineural Hearing Loss: A Review of Diagnosis, Treatment, and Prognosis. *Trends Amplif*. 2011;15(3):91-105. doi:10.1177/1084713811408349
- Schreiber BE, Agrup C, Haskard DO, Luxon LM. Sudden sensorineural hearing loss. *Lancet*. 2010;375(9721):1203-1211. doi:10.1016/S0140-6736(09)62071-7
- Nosrati-Zarenoe R, Arlinger S, Hultcrantz E. Idiopathic sudden sensorineural hearing loss: Results drawn from the Swedish national database. *Acta Otolaryngol*. 2007 Nov;127(11):1168-75. doi: 10.1080/00016480701242477.
- Shaia FT, Sheehy JL. Sudden sensori-neural hearing impairment: a report of 1,220 cases. *Laryngoscope*. 1976 Mar;86(3):389-98. doi: 10.1288/00005537-197603000-00008.
- Huy PT, Sauvaget E. Idiopathic sudden sensorineural hearing loss is not an otologic emergency. *Otol Neurotol*. 2005 Sep;26(5):896-902. doi: 10.1097/01.mao.0000185071.35328.6d..
- Xenellis J, Karapatsas I, Papadimitriou N, Nikolopoulos T, Maragoudakis P, Tzagkaroulakis M. et al. Idiopathic sudden sensorineural hearing loss: prognostic factors. *J Laryngol Otol*. 2006 Sep;120(9):718-24. doi: 10.1017/S0022215106002362
- Sakata T, Kato T. Feeling of ear fullness in acute sensorineural hearing loss. *Acta Otolaryngol*. 2006 Aug;126(8):828-33. doi: 10.1080/00016480500527268.
- Murphy-Lavoie H, Piper S, Moon RE, Legros T. Hyperbaric oxygen therapy for idiopathic sudden sensorineural hearing loss. *Undersea Hyperb Med*. May-Jun 2012;39(3):777-92.
- Bhatt JM, Bhattacharyya N, Lin HW. Relationships between tinnitus and the prevalence of anxiety and depression. *Laryngoscope*. 2017 Feb;127(2):466-469. doi: 10.1002/lary.26107.
- Penido NO, Cruz OL, Zanoni A, Inoue DP. Classification and hearing evolution of patients with sudden sensorineural hearing loss. *Braz J Med Biol Res*. 2009 Aug;42(8):712-6. doi: 10.1590/s0100-879x2009000800004.
- Chau JK, Lin JR, Atashband S, Irvine RA, Westerberg BD. Systematic review of the evidence for the etiology of adult sudden sensorineural hearing loss. *Laryngoscope*. 2010 May;120(5):1011-21. doi: 10.1002/lary.20873.
- Nelson JJ, Chen K. The relationship of tinnitus, hyperacusis, and hearing loss. *Ear Nose Throat J*. 2004 Jul;83(7):472-6.
- Konstantina G, Fildissis G, Zyga S, Baltopoulos G. The Clinical Efficacy of Hyperbaric Oxygen Therapy in Idiopathic SSNHL and Tinnitus. *Health Sci J*. [Internet] 2015;10(1). Disponível em: <https://www.itmedicalteam.pl/articles/the-clinical-efficacy-of-hyperbaric-oxygen-therapy-in-idiopathic-sudden-sensorineural-hearing-loss-and-tinnitus.pdf>
- Joshua TG, Ayub A, Wijesinghe P, Nunez DA. Hyperbaric oxygen therapy for patients with Sudden sensorineural hearing loss: a systematic review and meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2022 Jan 1;148(1):5-11. doi: 10.1001/jamaoto.2021.2685.
- Magalhães C, Oliveira N, Lopes G, Nakamura R, Fernandes T, Rodrigues MR. Surdez neurosensorial súbita idiopática e acufeno: o papel da oxigenoterapia hiperbárica. *Revista Portuguesa de Otorrinolaringologia e Cirurgia de Cabeça e Pescoço* [Internet] 2014 Dez 52(4):205-10. Disponível em: <https://journalsporl.com/index.php/porl/article/view/435>.
- Olex-Zarychta D. Hyperbaric oxygenation as adjunctive therapy in the treatment of sudden sensorineural hearing loss. *Int J Mol Sci*. 2020 Nov 14;21(22):8588. doi: 10.3390/ijms21228588.
- Aazh H, Salvi R. The Relationship between severity of hearing loss and subjective tinnitus loudness among patients seen in a specialist tinnitus and hyperacusis therapy clinic in UK. *J Am Acad Audiol*. 2019 Sep;30(8):712-719. doi: 10.3766/jaaa.17144.
- Siegel LG. The treatment of idiopathic sudden sensorineural hearing loss. *Otolaryngol Clin North Am*. 1975 Jun;8(2):467-73.
- McCombe A, Baguley D, Coles R, McKenna L, McKinney C, Windle-Taylor P. et al. Guidelines for the grading of tinnitus severity: the results of a working group commissioned by the British Association of Otolaryngologists, Head and Neck Surgeons. *Clin Otolaryngol Allied Sci*. 2001 Oct;26(5):388-93. doi: 10.1046/j.1365-2273.2001.00490.x.
- Oliveira V, Meneses R. Balanço da Utilização da Versão Portuguesa do Tinnitus Handicap Inventory (THI). *Repositório Científico do Instituto Politécnico do Porto*. [Online] 2011 Available from: https://recipp.ipp.pt/bitstream/10400.22/1922/4/PTE_VascoOliveira_2011.pdf
- Korpinar S, Alkan Z, Yigit O, Gor AP, Toklu AS, Cakir B. et al. Factors influencing the outcome of idiopathic sudden sensorineural hearing loss treated with hyperbaric oxygen therapy. *Eur Arch Otorhinolaryngol*. 2011 Jan;268(1):41-7. doi: 10.1007/s00405-010-1336-6.
- Sara SA, Teh BM, Friedland P. Bilateral sudden

sensorineural hearing loss: review. *J Laryngol Otol.* 2014 Jan;128 Suppl 1:S8-15. doi: 10.1017/S002221511300306X.

24.Topuz E, Yigit O, Cinar U, Seven H. Should hyperbaric oxygen be added to treatment in idiopathic sudden sensorineural hearing loss? *Eur Arch Otorhinolaryngol.* 2004 Aug;261(7):393-6. doi: 10.1007/s00405-003-0688-6.