Recent advances in management of idiopathic sudden sensorineural hearing loss by hyperbaric oxygen

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Abstract: Idiopathic sudden sensorineural hearing loss (ISSNHL) is a clinical condition with which most otolaryngologists are familiar The treatment of ISSNHL is still a controversy as there is no definitive line of treatment that takes the upper hand in enhancing the hearing threshold of the patients. These lines include short course systemic corticosteroids therapy, intra-tympanic injection of corticosteroids, hyperbaric oxygen and others.
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Introduction:

The National Institute of Deafness and Other Communication Disorders States defines sudden sensori neural hearing loss as the rapid loss of hearing threshold at least 30 dB in three consecutive frequencies within 3 days. Sudden sensorineural hearing loss is a medical emergency. It should not be misdiagnosed. Early detection and management will improve the chance of complete recovery (1).

National surveys in United Kingdom have estimated the incidence of sudden sensorineural hearing loss at between 5 and 30 cases per 100,000 populations per year. About 30 – 70 % of cases with ISSNHL shows spontaneous recovery even with no trial of treatment. The treatment of ISSNHL is still a controversy as there is no definitive line of treatment (2).

Anatomy of the inner ear:

The otic capsule lies within the petrous portion of the temporal bone containing a protective shell of bone the periotic labyrinth which surrounds the essential structure of the inner ear (Figure 1), the otic labyrinth The otic labyrinth is divided into three interconnected parts: the pars superior or vestibular labyrinth, The pars inferior or cochlea and the endolymphatic duct and Sac (3).

Stress response hypothesis in ISSNHL:

ISSHL may be the result of abnormal activation of cellular stress pathways involving nuclear factor kappa B (NFkB) within the cochlea. NFkB is a transcription factor that is present in virtually all cells within the body. It plays a key role in normal cellular physiology and in mediating the responses of a cell or a tissue to infectious, mechanical, or osmotic stresses (4).

Pathologic activation of NFkB can result in production of inflammatory cytokines and other stress-related proteins that can disrupt the homeostatic balance of a cell or tissue. For example, one effect of activation of NFkB that is well known and extensively studied is the production of the inflammatory cytokines interleukin-1 and tumor necrosis factor-a. Pathologic activation of NFkB within the supporting cells of the organ of Corti may be an important mechanism that results in ISSHL. Rapid progression of downstream events after NFkB activation (which is known to occur in other organ systems) can explain the sudden and often catastrophic nature of ISSHL. Transient activation of the system would result in spontaneous recovery of hearing (5).

Hyperbaric oxygen:

Hyperbaric oxygen therapy (HBOT) involves the intermittent inhalation of 100 percent oxygen in chambers pressurized above one atmosphere absolute. The treatment duration and number of sessions required depend on the reason for HBOT. Each treatment duration can vary from 45 to 300 minutes, although most treatments are in excess of 90 minutes, for a variable number of sessions**.** HBO is designed to increase oxygen delivery to local ischemic tissue and by variety of primary and secondary mechanisms facilitates wound healing (6).

Most oxygen carried in the blood is bound to hemoglobin, which is 97% saturated at atmospheric pressure. Some oxygen is however carried in solution, and this portion is increased at pressure due to Henry's Law, maximizing tissue oxygenation. When breathing normobaric air, arterial oxygen tension is approximately 100 mmHg, and tissue oxygen tension approximately 55 mmHg. However, 100% oxygen at 3 ATA can increase arterial oxygen tensions to 2000 mmHg, and tissue oxygen tensions to around 500 mmHg allowing delivery of 60 ml oxygen per litre of blood (compared to 3 ml/L at atmospheric pressure),

which is sufficient to support resting tissues without a contribution from hemoglobin. HBO has complex effects on immunity, oxygen transport and hemodynamic. The positive therapeutic effects come from a reduction in hypoxia and edema, enabling normal host responses to infection and ischemia (7).

The only absolute contraindication to HBO therapy is completely untreated pneumothorax. Furthermore, pregnants and patients with severe cardiac problem, chronic obstructive pulmonary disease, uncontrolled high fever, acute sinusitis, ear infection, optic neuronitis, retinal detachment, claustrophobia, previous pulmonary tuberculosis were considered as contraindicated (8).

In which period of the disease and how the HBO therapy should be used for SSNHL are still not clear. In a review study by ***Murphy-Lavoie et al***.,(9) although the proposed HBO treatment depended on the severity and duration of disease and response to treatment, the treatment recommended was 10–20 sessions of 100 % oxygen at 2–2.5 ATA pressure for 90 min daily.

In a study by ***Inci et al***.(10), patients who had not responded to medical treatment during the first 14 days were treated with HBO and about 55 % showed improvement. There are also some other studies which show that HBO therapy is useful in the early period. ***Muzzi et al***.(11) reported that starting HBO therapy during the first 10 days was more effective. ***Nakashima et al***(12), reported that hearing gain would be better if HBO therapy was added to the conventional treatment in the first week of SSNHL when compared with the cases that received HBO therapy after the first week (13).

In a study done in 2013 by ***Erol et al***.(14), HBO therapy was performed at2.4 ATA pressure for 120 min daily for 20 days. 59 patients with SSNHL were categorized into three groups according to the time of initiation of HBO therapy. Recovery rates were similar in groups in whom HBO therapy was initiated between 1 and 7 days and 8 and14 days. Hearing gain was statistically lower in the group in whom HBO therapy was initiated after14th day. They found that starting HBO therapy in the first 14 days for patients presenting with SSNHL is statistically more useful than starting it after 14 days**.**

Combined treatment of ISSNHL by Steroids and hyperbaric oxygen:

Different treatment regimens like antioxidants, corticosteroids, vas odilatators, hyperbaric oxygen (HBO), or carbogen therapy have been described in the treatment of ISSNHL. Among these approaches, steroid treatment is the most common. Steroids can be applied systemically (intravenously or orally) or by intratympanic injection. Intratympanic injection of steroids (ITS) is regarded as effective, safe, and well tolerated, and was shown to be as sufficient as orally applied steroids (15).

In combination with HBOT, the overall success rate of ITS was superior when compared to i.v. steroid application. Many authors claim that best results are achieved when HBOT starts within 2 weeks and is combined with steroid treatment. The combination of HBOT with systemic steroid treatment was especially successful for patients with an initial hearing loss of more than 90 dB.

In a study done in ***2013*** by ***Capuano et al.***(16) on 300 patients, they were splitted into 3 groups: the intravenous steroid group, the hyperbaric oxygen group and a compined therapy group each consisted of100 randomly sampled patients. There was no statistically significant difference between the three groups. The proportion of patients with complete recovery was the highest in the IVS + HBO group (58/100) 58%, followed by the HBO group (24/100) 24% and the IVS group (20/100) 20% The ratio of patients responding to therapy was the highest in the IVS + HBO group (84/100) 84%, followed by the HBO group (70/100) 70% and the IVS group (68/100) 68% (Figure 2). In all the groups, the results were not significantly influenced ($p > 0.05$) by age, association with dizziness, hypertension, diabetes, dysthyroidism, or smoking habits. So they recommend consideration of HBO in conjunction with IVS for patients with ISSNHL.

However, the hearing recovery may be achievable even if the onset of SSNHL was several weeks to months ago, if the patients were attributed to HBOT immediately after ITS. In addition to the synergistic effort in reducing edema in the inner ear, authors assume that HBOT changes the permeability of the round window membrane allowing increased influx of steroids into the perilymph, especially into the basal turn of the cochlea, where dexamethasone levels can be expected to be the highest. This may explain the recovery of hearing not only in the low frequencies but also in the high frequencies that are more refractory to recovery treatment ***(17).***

Other lines of tratment in ISSNHL:

Oral steroids:

The rationale behind the use of steroid therapy is a potential decrease in any associated pathogenic inflammation and oedema. The use of oral corticosteroids is probably the most widely used therapeutic intervention in ISSNHL **(18).**

Intratympanic injection of steroids:

A multicenter randomized trial in 2011 by Rauch et al demonstrated equivalent hearing outcomes in patients treated with either oral prednisone or IT methylprednisolone. Other studies have suggested that a combination of oral and IT corticosteroids may be superior to treatment by either modality alone (19).

In a recent study done in 2015 by *Thomas et al* on 37 patients, 18 were treated with 10mg/mL of IT dexamethasone, and 19 were treated with 24 mg/mL of IT dexamethasone, A clinically significant improvement in PTA (defined as Q30 dB) was attained 10 of 19 patients in the 24-mg/mL group compared with only 3 of 18 patients in the 10-mg/ml group. There was a trend toward greater mean improvement in PTA in the 24-mg/ml group compared with the 10-mg/mL group. This study provides the first demonstration of superiority of IT dexamethasone at 24 mg/ml for the treatment of ISSNHL, with significantly better recovery of PTA compared with10 mg/ml. The study also recommended early start of the treatment for better results.

Explorative tympanotomy and sealing of the round window membrane:

The study of ***Daniel Kampfner et al*** in 2013 was on 101 patients of SSNHL, 87 patients presented with idiopathic SSNHL and 14 reported a triggering factor before hearing loss. Of these14 patients, 3 reported hearing loss after lifting a heavy load, one after lifting weights, one after intensive nose blowing, two after an operation (ipsilateral Janetta operation, implantation of an intrathecal morphine pump), two after craniocerebral injury (traumatic subarachnoidal haemorrhage, traumatic epidural haemorrhage), one patient after local manipulation with a hairpin in the auditory canal with perforation of the tympanic membrane, one after a blow to the ipsilateral ear and one patient after removal of a cast for a hearing aid. In addition, two patients suffered from sudden hearing loss after infections (meningitis, acute sinusitis).

The average improvement at the time of ear dressing removal (mean 10 days postoperatively) in the 4-PTA for the whole study group was 21.7 dB. In the 33 cases where an additional follow-up audiogram was available, a further average recovery of 13.4 dB compared to the initial postoperative results was recorded. In comparison to the preoperative results, the4-PTAs had improved by an average of 32.8 dB at this time.

Conclusion:

The treatment of ISSNHL is still a controversy as there is no definitive line of treatment that takes the upper hand in enhancing the hearing threshold of the patients. These lines include short course systemic corticosteroids therapy, intra-tympanic injection of corticosteroids, hyperbaric oxygen. Many authors recommend combined therapy with corticosteroids and HBO especially in early cases.

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