Alternobaric oxygen therapy in long-term treatment of Ménière's Disease

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Fattori B, De Iaco G, Nacci A, Casani A, Ursino F, Alternobaric oxygen therapy in long-term treatment of Ménière's Disease. Undersea Hyper Med 2002; 29(4): 260-270. Hyperbaric oxygen therapy (HBO_2) has been used for several years as a treatment for Menière's disease, particularly in Sweden. In this study continuous variations in pressure (from 1.7 to 2.2 ATA; alternobaric oxygen therapy: ABOT) were used to decrease endolymphatic hydrops, the typical histopathological substrate of Menière's disease by increasing hydrostatic pressure and mechanical stimulation of the endolymphatic flow toward the duct and the endolymphatic sac, which produces a consequent increase in the dissolved O_2 content in the labyrinth liquid, which should contribute to recovering cell metabolism and restoring cochlear electrophysiological function to normal. An experimental group of 20 patients suffering from unilateral Menière's disease received a total of 15 ABOT treatment sessions during the acute episodes. Treatment foresaw two days without therapy every five days of application. Maintenance treatment consisted of one session per day for five consecutive days every month for one year. Thereafter, during the second, third, and fourth years of treatment, patients were submitted to one session per day for five consecutive days every three months. A control group of 18 patients suffering from Menière's disease was treated with 10% glycerol I.V. (during the acute episodes) and with betahistine (8 mg x 3/day) in the periods in between. Mean pure tone average (PTA in dBHL) hearing thresholds at octave frequencies from 500 to 3,000Hz, and frequency of episodes of vertigo and tinnitus, both after 15 days of treatment and at the end of a four-year follow-up, were compared for both groups according to the 1995 Committee on Hearing and Equilibrium criteria. No statistically significant differences were found between the two groups at the end of the first 15 days of treatment. However, at the end of the follow-up period, patients treated with ABOT had significantly fewer vertiginous episodes and improved PTAs and tinnitus compared to the controls. The results support the use of ABOT as a valid alternative to drugs in the long-term treatment of Menière's disease.

alternobaric oxygen therapy, hyperbaric oxygen therapy, pressure chamber, Ménière's Disease.

INTRODUCTION

Endolymphatic hydrops is considered to be the fundamental histopathological substrate of Ménière's disease (1,2). Experimental animal studies have demonstrated that endolymphatic pressure can cause damage to both vestibular and cochlear receptors (3-9). Thus, many therapeutic protocols for treating Menière's disease have been devised to decrease relative increases in pressure in the labyrinth liquid.

Besides traditional treatment with diuretic and/or osmotic drugs, the Swedish Medical School at the beginning of the 1970s introduced the use of a pressure chamber (10-12) in both

hyper- and hypobaric conditions. Most patients were treated with hypobaric pressure during the acute episode (11-16), while some patients have been treated with hyperbaric therapy (10,17,18).

The high percentage of oxygen administered in a pressurised environment for therapeutic reasons (Hyperbaric Oxygen Therapy: HBO_2) produces an increase in the quota of O_2 dissolved in the plasma, as well as an increase in partial pressure of O_2 in the inner ear (19,20). The respiratory mixture passing through the Eustachian tube also produces O_2 saturation in the middle ear space. This produces consequently, via the round window, an increase in the amount of O_2 physically dissolved in the labyrinth liquid (7).

A greater availability of oxygen presumably permits recovery of cell metabolism, particularly in Na+-K+ pump function and electrophysiological function; consequently labyrinth and cochlear ionic balance are restored (21). Moreover, at a systemic level, HBO_2 is responsible for a decrease in hematocrit and viscosity values, hence permitting greater fluidity of the blood and consequently an improved microcirculation (19,20).

Another effect of HBO_2 is a dynamic one: the inner ear, between the middle ear and the cerebrospinal spaces, is sensitive to variations in atmospheric pressure (4-9). The increases and variations in pressure caused by the treatment assist the downflow of endolymph through the endolymphatic sac and duct toward the cerebrospinal region. This re-activates the pressure regulating system within the inner ear, which had become compromised as a result of the disease (7,22-24).

This study reports the results of a four-year follow-up of 20 patients affected with Menière's disease who were submitted to periodic sessions in hyperbaric chamber. The sessions were not carried out at constant pressure, as described in the previous text, but under continually varied levels of pressure (Alternobaric Oxygen Therapy: ABOT). The results were compared with those obtained in a group of patients treated with one of the pharmacological drugs most commonly used in these cases (osmotic drugs during the acute attacks and betahistine in between-episode periods).

MATERIALS AND METHODS

The study was performed on a group of 20 unilateral Ménière's disease patients (10 males and 10 females) seen between the years 1992 and 1996; their ages ranged between 29 and 61 years (mean = 48.6 ± 13.1SD years), and all were treated with ABOT. Subjects were selected according to the criteria recommended by the 1995 Committee on Hearing Equilibrium (25), as shown in Table 1.

Table 1: ***Criteria for inclusion***

VERTIGO
• Objective vertigo with or without neurovegetative symptoms
• Duration from 20 minutes to several hours
• No loss of consciousness
• Recurring episodes

HYPOACOUSIA

- Documented hearing loss, either unilateral or bilateral for medium-low frequencies, or pantonal
- Hearing loss must come under one of the following types:

1. *The average (arithmetic mean) of hearing threshold at 0.25, 0.5, and 1kHz is 15 dB or more higher than the average of 1, 2, and 3kHz;*
2. *In unilateral cases, the average of threshold values at 0.5, 1, 2, and 3kHz is 20 dB or more poorer in the ear in question than on the opposite side;*
3. *In bilateral cases, the average of threshold values at 0.5, 1, 2, and 3kHz is greater than 25 dB in the studied ear.*

Parameters that excluded patients from treatment with ABOT are summarised in Table 2.

Table 2: ***Criteria for exclusion***

1. Probable form of Menière's disease;
2. Possible form of Menière's disease;
3. Diagnosis of Menière's disease but undergoing treatment with osmotic drugs (like Glycerol);
4. Altered tubal function recorded with tympanometry;
5. Pregnancy;
6. Bullous emphysema;
7. Evolutive asthma;
8. Episodes of spontaneous pneumothorax;
9. Epilepsy;
10. Otitis and/or recurring sinusitis;
11. Claustrophobia;
12. Inability to compensate (compensation must be spontaneous or, at the most, achieved by swallowing);
13. Ischemic or congestive heart disease;
14. Arterial hypertension resistant to pharmacological treatment;
15. Restrictive and/or obstructive lung disease;
16. Closed-angle glaucoma, detachment of the retina even if treated surgically.

The onset of the disease could be traced to 3 to 7.2 years before the start of the treatment (mean = 5.2 years) with an average of 0.6 episodes per month in the six months prior to the therapy. During acute episodes, the patients were submitted to pressurization alternated with depressurization, with pressure variations ranging from 1.7 to 2.2 ATA (ABOT). The initial stage of the treatment included a total of 15 sessions, with an interruption of two days every five days. Maintenance treatment consisted of one session per day of ABOT, applied in the same

manner, for 5 consecutive days every month for one year; thereafter, one session was applied daily for five days every third month for the second, third, and fourth years.

The sessions took place in a multi-person pressure chamber (Galeazzi-Drass®) and treatment pressures were achieved at a constant, fixed rate (one meter/minute) to facilitate compensation either spontaneously or by swallowing. Once treatment pressure was reached, the patients breathed pure oxygen through an oro-nasal mask for two periods of 42 minutes, with an interval in between of five minutes when air was breathed.

A control group of 18 patients affected with unilateral Ménière's disease (10 males and 8 females; mean age = 46.8±11.3SD years) was selected according to the same criteria as for the experimental group. These patients were treated with 10% glycerol I.V. during the acute episodes and with betahistine (8 mg x 3/day) during periods of remission. The first signs of the disease in this group had arisen 3 to 8 years (mean = 4.2 years) prior to being referred for treatment, with a 2.7 months symptom-free period prior to beginning therapy and with an average of 0.5 episodes of vertigo per month throughout the 6 months preceding treatment.

All patients in both groups underwent a complete otoneurological examination before and after every cycle of treatment. Eye movement was studied with videonystagmography (VNG Ulmer System 3.1®): saccade movement and smooth-pursuits were analyzed, and spontaneous, position, and positional or head-shaking nystgamus were evaluated. Vestibular function was tested with calorics according to Fitzgerald-Hallpike (26), assessing the response in terms of labyrinth preponderance (LP) and directional preponderance (DP), using the Jonkees formula (27) (normal reference standards were LP < 20%; DP < 24%).

Hearing capacity was quantified with pure-tone audiometry after testing tubal function by means of tympanometric tests. Hearing loss was calculated according to pure-tone average (PTAs in dBHL) for 500, 1,000, 2,000 and 3,000Hz. To preserve homogeneity, patients having hypoacousia in the higher frequency ranges were excluded from the study.

Analysis of the response to ABOT treatment was performed according to the criteria proposed by the 1995 Committee on Hearing and Equilibrium (25) summarized in Table 3.

Table 3: ***Assessment of the alternobaric treatment***

HYPOACOUSIA
Staging:
Staging is based on the pure-tone average at 0.5, 1, 2, and 3kHz, in the worst audiogram recorded during the six months prior to treatment. This is the same audiogram used in the basic assessment of efficacy of the treatment on hearing loss. Staging must be performed only in cases of diagnosed or certain Menière's disease.
• *Stage 1*: PTA at 0.5, 1, 2, 3kHz: ≤ 25 dB
• *Stage 2*: PTA at 0.5, 1, 2, 3kHz: 26-40 dB
• *Stage 3*: PTA at 0.5, 1, 2, 3kHz: 41-70 dB
• *Stage 4*: PTA at 0.5, 1, 2, 3kHz: > 70 dB

TINNITUS

Self-assigned scores from + to +++

VERTIGO

Classes:

The numeric value is calculated as follows: (X/Y) x 100, rounded to the nearest number; *where X* is the average of the number of episodes/per month for six months going from the 18th to the 24th month after treatment *and Y* is the average of the number of episodes/per month in the six months prior to treatment.

Numeric value	**Class**
0	A (complete control over the episodes)
1-40	B
41-80	C
81-120	D
> 120	E

Quantification of hearing loss was based on an evaluation of the PTA: patients were subdivided into stages, and improvement in PTA of 10 dB or greater was considered a positive response to the treatment. Vertigo was assessed according to the average number of episodes per month during the six-month period from the 18th to the 24th month after therapy, comparing this average with that of the number of episodes that occurred during the six months prior to treatment. Intensity of tinnitus was quantified on a subjective basis, ranging from + as minimum intensity to +++ as maximum intensity.

All patients followed a low salt diet with low liquid intake on an empty stomach.

Statistical analyse of variance were conducted on the PTA measurements and other variables (i.e., tinnitus, spontaneous, positional and head-shaking nystagmus, LP). Pearson chi square tests were used to assess associations among categoric variables.

RESULTS

Table 4 summarizes the data for the experimental (ABOT) subjects at basal conditions; 13 (65%) cases had flat sensorineural hearing loss (FHL: Flat Hearing Loss) with a mean PTA of 62.25 dB; 7 (35%) cases had sensorineural hypoacousia that was limited to the lower and medium frequencies (USHL: Up-Sloping Hearing Loss) with mean a PTA of 45.4 dB. Tinnitus was reported in all patients. The results of the vestibular examination are summarized therein.

Table 4

Table 4: *Basal Conditions. Number, Stage, and PTA of Patients with FHL and with USHL. Intensity of Tinnitus and the VNG Data Recorded in the ABOT and Control Groups.*

	Basal Conditions													
	Hearing loss						Tinnitus			Vestibular examination				
	FHL			USHL										
Patients	*N°*	*Stage*	*PTA*	*N°*	*Stage*	*PTA*	+	++	+++	*Spont. ny*	*HS ny*	*Pos ny*	*LP*	*LP + DP*
ABOT 20	13 (65%)	10 Stg3 3 Stg4	62.25 dB	7 (35%)	2 Stg2 5 Stg3	45.4 dB	4	10	6	14 (70%)	20 (100%)	6 (30%)	20 (100%)	6 (30%)
Contr. 18	11 (61.1%)	1 Stg2 7 Stg3 3 Stg4	58.5 dB	7 (38.9%)	3 Stg2 4 Stg3	40.7 dB	3	10	5	13 (72.2%)	18 (100%)	5 (27.8%)	18 (100%)	10 (55.5%)

FHL: Flat Hearing Loss;USHL: Up-Sloping Hearing Loss
Vestibular examination: Spontaneous nystagmus (Spont.ny); Head Shaking nystagmus (HS ny); Positional nystagmus (Pos ny); Labyrinth Preponderance (LP); Directional Preponderance (DP).

For the control subjects at basal conditions, FHL-type hypoacousia was present in 11 (61.1%) cases with a mean PTA of 58.5 dB, and 7 cases (38.9%) had USHL-type hypoacousia with a mean PTA of 40.7 dB. Tinnitus was present in all 18 patients. The results of the vestibular examination are summarized in Table 4.

At the end of the first cycle of 15 sessions, no statistically significant differences were found among the category of variables for the ABOT and control groups. Although the PTAs between the groups were not significantly different ($F = 0.34$; $p = 0.71$), improvement was noted for the USHL hypoacousia cases treated with ABOT (19.5 dB) compared to the control group (15 dB) and for the FHL hypoacousia cases (ABOT = 24 dB; controls = 15 dB).

Likewise, the nominal logistic regression analysis showed no significant differences among the variables considered between the two groups. The best therapeutic response was seen in the patients treated with ABOT, both for tinnitus (ABOT = 68%, controls = 50%) and keeping the vertigo symptoms under control (ABOT = 80%; controls = 66.6%).

FOLLOW-UP

Improvement in vestibular function was assessed by comparing the average number of episodes of vertigo per month suffered during the six months prior to treatment, with the average number of episodes per month occurring in the span of time between the 42nd and the 48th month after the start of therapy. Improvement in PTA hearing threshold was calculated in all patients by comparing their worst audiogram recorded during the six months prior to therapy with their worst audiogram recorded between the 42nd and the 48th month after starting therapy.

Table 5 summarizes the data for the experimental (ABOT) subjects at follow-up. The patients who received ABOT were grouped for vertigo as follows: 16 in Class A (80%), 2 in Class B (10%), 2 in Class C (10%), and none in Class D (0%) as depicted in Figure 1. An improvement of at least 10 dB in the PTA was seen in 14 cases (70%: 7 of the 13 FHL and all 7 USHL) with the USHL losses showing significantly more recovery of hearing ($p = 0.012$) than

the FHL losses. Of the patients with FHL, 2 were at stage 1, 3 at stage 2, 6 at stage 3, and 2 at stage 4. In cases showing hearing improvement, the PTA dropped from 62.25 dB to 51 dB. Of patients with USHL, 4 were at stage 1 and 3 were at stage 2. The PTA improved in these cases with a drop from 45.4 to 25.5 dB (Table. 5 and 6).

Table 5

Table 5: *At the End of the Four-Year Follow-up: Number, Stage, and PTA of the Patients with FHL and with USHL. Intensity of Tinnitus and the VNG Data Recorded in ABOT and Control Groups.*

Four-Year Follow-up														
	Hearing loss						Tinnitus			Vestibular examination				
	FHL			USHL										
Patients	N°	*Stage*	*PTA*	*N°*	*Stage*	*PTA*	+	++	+++	*Spont. ny*	*HS ny*	*Pos ny*	*LP*	*LP + DP*
ABOT 20	13	2 Stg1 3 Stg2 6 Stg3 2 Stg4	51dB	7	4 Stg1 3 Stg2	25.5dB	3	8	4	0	3 (15%)	0	11 (55%)	0
Contr. 18	11	1 Stg1 2 Stg2 5 Stg3 3 Stg4	48dB	7	3 Stg1 2 Stg2 2 Stg3	28dB	2	3	1	0	5 (27.7%)	0	13 (72.2%)	0

FHL: Flat Hearing Loss; USHL: Up-Sloping Hearing Loss
Vestibular examination: Spontaneous nystagmus (Spont.ny); Head Shaking nystagmus (HS ny); Positional nystagmus (Pos ny); Labyrinth Preponderance (LP); Directional Preponderance (DP).

Table 6: *Hearing threshold improvement in the two groups of patients after a four-year follow-up.*

	ABOT Group	Control Group	
Number of Patients	**14 (70%)**	**8 (44.4%)**	**p = 0.001**
PTA **FHL**	**11.25 dB**	**10.5 dB**	
PTA **USHL**	**19.9 dB**	**12.7 dB**	

FHL = Flat Hearing Loss
USHL = Upward Sloping Hearing Loss

The VNG revealed head-shaking nystagmus in 3 cases (15%) and pathological LP in 11 (55%).

A persistent improvement in tinnitus was recorded in 9 cases (45%) while it disappeared in 5 (25%) self-scoring ultimately changed to 3+, 8++, and 4+++ as seen in Table 5.

Figure 1 shows that of the control group, 7 patients (38.9%) belonged to Class A, 3 (16.7%) to Class B, 6 (33.3%) to Class C, and 2 (11.1%) to Class D.

	Class A	Class B	Class C	Class D	PTA
ABOT	80	10	10	0.2	70
Control	38.9	16.7	33.3	11.1	44.4

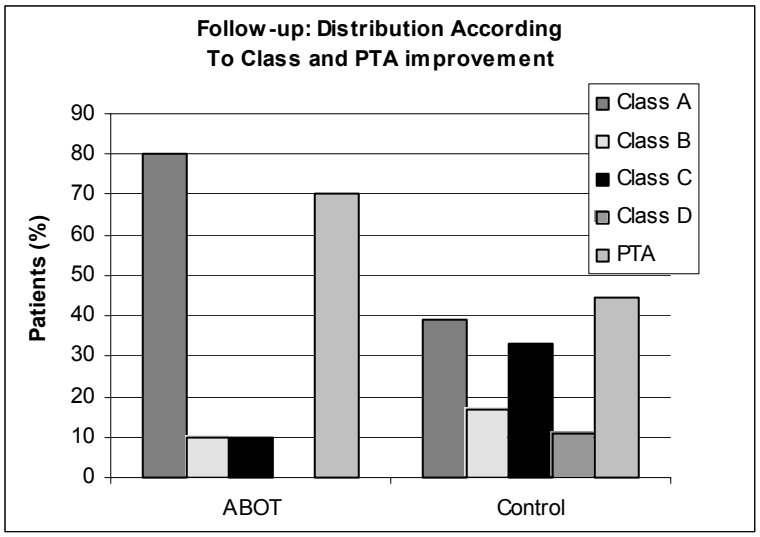

Fig. 1. Patient distribution at follow-up according to class and PTA improvement.

The PTA improved in 8 (44.4%) subjects: 4 FHL (22.2%) and 4 USHL (22.2%). Of the FHL patients, 1 was at stage 1, 2 at stage 2, 5 at stage 3, and 3 at stage 4. In these latter patients, the overall PTA value dropped from 58.5 dB to 48 dB. On the other hand, the classification of USHL patients showed 3 at stage 1, 2 at stage 2 and 2 at stage 3. The overall PTA in these cases went from 40.7 dB to 28 dB (Table 5 and 6).

The VNG revealed head-shaking nystagmus in 5 cases (27.7%) and pathological PL in 13 (72.2%). Tinnitus improved in 6 (33.3%) cases; self-scoring ultimately changed to 2+, 3++ and 1+++ as seen in Table 5.

SUMMARY

Treatment with alternobaric oxygen therapy produced favorable results, particularly in long-term maintenance treatment. Analysis after 15 sessions showed that the results were statistically similar ($p > 0.1$) to those obtained for the controls, both for improvement in acute vertigo symptomatology (ABOT, 80%; controls, 66.6%) and improvement (≥ 10 dB PTA) in hypoacousia (ABOT, 60%; controls, 50%).

After four years of follow-up, the compensated vestibular deficits (pathological LP with no signs of other involvement of the labyrinth) were statistically greater ($p = 0.01$) in the patients treated with ABOT (88%) than in the controls (72.3%). The most encouraging result was the statistically significant decrease ($p < 0.05$) in the number of acute attacks of vertigo in the ABOT group from the 42nd to the 48th month after the start of treatment compared to the number

suffered during the 6 months prior to the beginning of treatment. This effect was even more evident when the results were compared to those obtained for the controls in the same period of time. Significant differences were found between Class A and C patients when comparing those treated with ABOT to the controls ($p = 0.004$ and $p = 0.02$, respectively). The number of patients having at least a 10 dB improvement in PTA was significantly better for the experimental group (ABOT, 70%; controls, 44.4%; $p = 0.001$). Moreover, the ABOT patients had significantly ($p = 0.05$) less tinnitus than the controls.

DISCUSSION

Treatment of Ménière's disease in pressure chambers was introduced many years ago by Swedish school physicians. Some authors reported their experience with hyperbaric (6,10-13,18) and others with hypobaric treatments (14,15). In our study, we used alternobaric treatment since we believe it has a greater effect upon the endolymphatic hydrops, both varying the hydrostatic pressure during treatment and mechanically stimulating the flow of endolymph from the labyrinth to the endolymphatic sac and the duct. The results with ABOT were compared with those obtained in a group of patients treated with one of the pharmacological drugs most commonly used in these cases: osmotic drugs during the acute attacks and betahistine in between-episode periods.

When the human body is exposed to variations in pressure, it undergoes physical or mechanical alterations only where it can be compressed, such as in gas cavities separated from the outside by a membrane, as in the case of the middle ear. According to the Boyle and Mariotte law, an increase in atmospheric pressure causes an introflexion of the tympanic membrane and, hence, a decrease in the volume of the middle ear and an increase in pressure on the tympanic membrane, while, at the same time, and within the cavity of the middle ear, the walls of the Eustachian tube collapse. Tympanic depression increases pressure on the oval window and, consequently, causes outward flexion of the round window membrane. Any voluntary movement performed for compensating this (like swallowing) opens the Eustachian tube and causes an increase in volume in the middle ear, thus restoring the original balance. The opposite occurs with a decrease in atmospheric pressure (15,23,24).

Because fluids cannot be compressed, any variation in pressure inside the perilymphatic compartment brings about alterations in endolymphatic pressure; consequently, endolymphatic flow is facilitated toward the cerebrospinal spaces, through a passive aperture of the temporarily closed endolymphatic duct and, quite possibly, also because of venous decongestion (7). The continuous congestion and decongestion of the veins associated with variations in pressure submit the microvascular system to continuous variations in calibre, and with 100% pressurised oxygen that is breathed simultaneously, there is forced oxygenation of the temporarily malfunctioning hypoxic nervous cells in the area around the damage (the so-called twilight ischemic zone) (19,20,28). These events have been confirmed in experiments performed in animals (8,15), although there are few data for humans (8,16). The improvements achieved with ABOT may be due to the continuous pressure stress (relative overpressure and underpressure) on the endolymphatic compartment and a subsequent improvement in the outflow of endolymph toward the cerebrospinal fluids (7,22-24,29,30).

Another point to consider is the overall benefit of breathing HBO_2. PO_2 in the inner ear increases because gas passes through the round window, increasing the amount of physically dissolved O_2 in the labyrinth liquid (21,28). Moreover, cell metabolism is facilitated, and in particular, there is a greater oxygen supply to the Na+/K+ pumps that play an important role in

maintaining ionic balance, thus enabling better electrophysiological functioning of the labyrinth (21).

In our study, we based our evaluation of therapeutic response on the criteria of the 1995 Committee, which recommends exact parameters for assessing both hearing and vestibular improvement, and which are required of all studies of Ménière's disease. Since two of three pathognomic symptoms of Ménière's disease (tinnitus and vertigo) are subjective, the presence of a placebo effect cannot be excluded *a priori*. Nevertheless, we believe that the lengthy observation period (four years) reduced the possibility of any major placebo influence.

These results with ABOT in long-term management of Ménière's disease confirm the efficacy of this type of therapy compared to pharmacological treatment with betahistine and glycerol. We achieved fewer and less intense episodes of vertigo (sometimes difficult to assess because of their variability) with ABOT, which allowed the patients to resume working much more quickly, hence reducing their disability time. Furthermore, the significant improvements in PTA in patients receiving ABOT brought more rapid improvement in speech discrimination.

REFERENCES

1. Schucknecht HF. Pathology of Ménière's disease. Otolaryngol Clin North Am 1968;1:331-337.
2. Fraysse B, Alonso A, House W. Ménière's disease and Endolymphatic Hydrops Clinical-histopathological correlations. Ann Otol Rhinol Laryngol 1980; Suppl. 76,89:1-22.
3. Ingelstedt S, Ivarsson A, Tjernström Ö. Vertigo due to relative overpressure in the middle ear. An experimental study in man. Acta Otolaryngol (Stockh) 1974;78:1-13.
4. Densert O, Carlborg B, Stagg J. Transmission of Low Frequency Pressure Steps to the Perilymphatic Fluid. Acta Otolaryngol (Stockh) 1981;91:55-64.
5. Tjernström Ö. Further studies on alternobaric vertigo. Acta Otolaryng (Stockh) 1974;78:221-231.
6. Densert O, Ingelstedt S, Ivarrson A, Pedersen L. Immediate restoration of basal sensorineural hearing (MB Ménière) using a pressure chamber. Acta Otolaryngol (Stockh) 1975;80:93-100.
7. Tjernström Ö. Effects of middle ear pressure on the inner ear. Acta Otolaryngol (Stockh) 1977;83:11-15.
8. Kitahara M, Suzuki M, Kodama A. Equilibrium of inner and middle ear pressure. Acta Otolaryngol (Stockh) 1994;Suppl 510:113-115.
9. Suzuki M, Kitahara M, Kitano H. The influence of middle ear pressure changes on the primary vestibular neurons in guinea pigs. Acta Otolaryngol (Stockh) 1994;Suppl 510:9-15.
10. Densert B, Densert O. Overpressure in treatment of Ménière's disease. Laryngoscope 1982;92:1285-1291.
11. Ingelstedt S, Ivarsson A, Tjernström Ö. Immediate relief of symptoms during acute attacks of Ménière's disease. Acta Otolaryngol (Stockh) 1976;82:368-378.
12. Tjernström Ö, Casselbrant M, Ivarsson A. Hearing improvement in attacks of Ménière's disease treated with pressure chamber. Adv ORL 1979;25:54-60.
13. Tjernström Ö, Casselbrant M, Harris S, Ivarsson A. Current status of pressure chamber treatment. Otolaryngol Clin North Am 1980;13:723-729.
14. Van Deelen GW, Hulk J, Huizing EH. The use of the underpressure chamber in the treatement of patients with Ménière's disease. J of Laryngol and Otol 1987;101:229-235.
15. Carlborg B, Farmer Jr J, Carlborg A. Effects of Hypobaric Pressure on the Labyrinth. Acta Otolaryngol (Stockh) 1990;110:389-393.
16. Kitahara M, Kodama A, Ozawa H, Izukura H. Pressure test for the diagnosis of Ménière's disease. Acta Otolaryngol (Stockh) 1994;Suppl 510:107-110.
17. Lamm CH, Walliser U, Schumann K, Lamm K. Sauerstoffpartialdruck-Messungen in der Perilymphe der Scala Tympani unter normo und Hyperbaer Bedingungen. HNO 1988;36:363-366.
18. Densert B. Effects of overpressure on hearing function in Ménière's disease. Acta Otolaryngol (Stockh) 1987;103:32-42.
19. Jain KK. Texthbook of Hyperbaric Medicine. Hogrefe & Huber (eds), Toronto, Ontario-Canada, 1990.
20. Wattel F, Mathiev D. Oxygénothérapie Hyperbare et Réanimation. Masson (ed), Paris, France, 1990.

21. Younger R, Longbridge NS. Effect of reduced atmospheric pressure on patients with fluctuating hearing loss due to Ménière's disease. J Otolaryngol 1984;13:76-82.
22. Fattori B, Ghilardi PL, Casani A, De Ciccio M, Vannucci G, De Iaco G. Hyperbaric oxygenation therapy in Meniere's disease. Proceedings of Third International Symposium on Meniere's disease. Rome, Italy, October 22,23 1994, pp493-496.
23. Fattori B, De Iaco G, Vannucci G, Casani A, Ghilardi PL. Alternobaric and Hyperbaric Oxygen therapy in the immediate and long-term treatment of Meniere's disease. Audiology, 1996;35,322-334.
24. Fattori B, Casani A, Ghilardi PL, Vannucci G, Nacci A, De Iaco G. Oxigen Therapy in the immediate and long-term treatment of Menière's disease. Proceedings of the 4th International Symposium on Menière's disease, Paris,1999 Kugler Ed..
25. Committee on Hearing and Equilibrium: Committee on Hearing and Equilibrium guidelines for the diagnosis and evaluation of therapy in Ménière's disease. Otolaryngol Head Neck Surg 1995;113:181-185.
26. Fitzgerald G, Hallpike CS. Studies in human vestibular function: Observations on the directional preponderance ("nystagmusbereitschaft") of caloric nystagmus resulting from cerebral lesions. Brain 1942;65:115-137.
27. Jongkees LBW. Which is the preferable method of performing the caloric test? Acta Otolaryng 1949;49:594-608.
28. Lamm CH, Lamm K. The effects of hyperbaric oxygen on the inner ear. In: Kindwall EP (ed) Proceedings of the eight International Congress on Hyperbaric Medicine. Best Publishing, San Pedro, California, S35.
29. Kitahara M, Kodama A, Ozawa H, Inoue S. A soundproof pressure chamber. Acta Otolaryngol (Stockh),1994;Suppl 510:82-86.
30. Kitahara M, Kodama A, Izukura H, Ozawa H. Effect of atmospheric pressure on hearing in patients with Ménière's disease. Acta Otolaryngol (Stockh) 1994;Suppl 510:111-112.