International Tinnitus Journal 1, 93-97 (1995)

Neurootological Evaluation of Tinnitus

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Abstract: We analyse the neurootological data of patients attended in the Ear, Nose and Throat (E.N.T.) department of the Centro Hospitalar de Vila Nova de Gaia for a tinnitus problem. We submitted these patients to our neurootological routine evaluation. This approach is justified in a tinnitus patient because the cochleovestibular system is a unit and acts as a whole. We characterise the population that came to us by sex and mean age. The profile of these patients is then analysed by our neurootological routine evaluation, which comprises the history taking and audiometric as well as equilibriometric investigations. The results of the audiovestibulometric examinations - pure tone audiometry, vocal audiometry, and Brain Evoked Response Audiometry (B.E.R.A.), Cranio-Corpo-Graphy (C.C.G.), Electronystagmography (E.N.G.) - are discussed. We concluded that many tinnitus patients, even those who had no vestibular symptoms, showed some disturbances in the vestibular tests. This fact highlights the need for a complete cochleovestibular investigation in all patients complaining about tinnitus.

INTRODUCTION

Tinnitus is a widespread symptom that mortifies patients and frustrates doctors. It may be the only symptom complained by patients, but commonly it is associated with neurosensory hearing loss and/or vertigo. Shulman and his co-workers have shown in their studies, through routine cochleovestibular testing, that there is a higher incidence of peripheral vestibular dysfunction in patients suffering from tinnitus, even without accompanied vertigo.[12,13]

We think, like Shulman and others,[12,13] that the cochleovestibular system should be considered as a whole and studied as such. Therefore, in order for the investigation of tinnitus to be complete, one must include the evaluation of the vestibular function of the ear, as well as the auditory. For that reason, all our patients undergo a complete routine neurootological evaluation.

MATERIAL AND METHODS

The aim of this study is to evaluate the changes in the neurootological evaluation of the patients suffering from tinnitus.

All patients with a tinnitus problem are considered by our department for an E.N.T. consultation. We excluded from this study, those patients who had an identifiable middle ear disease, such as chronic otitis, tympanic perforations, or tympanosclerosis.

We investigated 44 patients, 19 men and 25 women, with a mean age of 48-years (standard deviation being 12).

The patients underwent our routine neurootological examination which comprises:

- History - We use, for statistical purposes, a standardised questionnaire based on Claussen's NODEC[3].

- E.N.T. examination

- Neurological routine examination

- Audiometric evaluation

Audiometry - Our audiologists routinely perform the tonal (aerial and bone conduction) and vocal audiometry and supraliminal tests - the Short Increment Sensitivity Index (S.I.S.I.) test and the Tone Decay, searching for recruitment and abnormal auditory adaptation, respectively.

Impedancimetry - The tympanogram, stapedial reflexes, reflex decay and Metz test.

Brain Evoked Response Audiometry (B.E.R.A.) - We record the B.E.R.A. using a click of increasing intensities of 60, 80, 100 and 120 dB SPL sometimes with a contralateral masking. For this study we only considered the measurements made with the higher intensity (120 dB SPL).

- Vestibulometric evaluation

Cranio-Corpo-Graphy (C.C.G.) - The C.C.G. is described by Claussen[1,3,4,6] and is, in our opinion, a very good and reliable method to assess and evaluate the vestibulospinal pathway. The patient's head and body movements are recorded by a camera, as he performs

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the classical Unterberger-Fukuda's stepping test and Romberg's standing test. The patient is asked to use a hard hat with two small electrical bulbs in the saggital plain; one above the forehead and the other above the occiput. The patient is further fitted with two more lamps taped onto each shoulder. The test is performed in a darkened room. An eye mask ensures that the patient is not able to see. The recording camera picks up the patients light tracings as reflected through a convex mirror, which is attached to the ceiling above the camera. Therefore, the craniocorpogram looks like a radar image of the head and shoulder movements. The C.C.G. results are quantified through parameters, which are measured out directly from the test chart.

Electronystagmography - Electronystagmography (E.N.G.), as described by Schott (1922) in Cologne, is a record of the electrical activity of the eye movements. It is based on the dipole concept of the human eye. We use an Electronystagmograph with three channels recording the vertical and horizonal movements of the eye. We look for spontaneous and fixation nystagmus. The nystagmus may be elicited by a variety of stimuli, either vestibular, optokinetics or others. We routinely use the calorics with an air stimulator, irrigating the ear during 30 seconds, at a rate of approximately 5-6 litres per minute at the temperature of 45 and 27 degrees Celsius. We usually perform the rotatory tests with an acceleration of three degrees per second square during 30 seconds and then there is a relapsing time of three minutes with constant velocity, therefore, with no vestibular stimulation. The optokinetics are made in this period by asking the patient to open his/her eye and look forward. Afterwards, there is a deceleration period equal but opposite to the acceleration one.

RESULTS

HISTORY

Tinnitus was bilateral in 40% of the patients. There was no significant difference between right and left ear involvement (Table 1).

Table 1. Symptoms

Tinnitus bilateral	40 %
Tinnitus unilateral	60 %
Tinnitus right ear	54 %
Tinnitus left ear	46 %
Hearing Loss	50 %
Unsteadiness	18 %
Headache	5 %

Regarding the existence of other symptoms we state the following:

1) Half of the patients also have some degree of hearing loss.
2) When specifically asked 18% of our sample mentioned unsteadiness or other equilibrium disturbance.
3) 5% had significant headaches.
4) In 40% of the cases tinnitus was the only symptom.

AUDIOMETRIC EVALUATIONS

Pure Tone Audiometry - The values for the mean and standard deviation of the hearing loss in dB are shown in Table 2.

Table 2. Values for the mean and standard deviation of the hearing loss in each frequency

	250	500	1000	2000	4000	8000
Mean (dB HL)	22	22	22	22	33	37
StD	22	25	23	22	26	28

We found that 58% of the patients in our sample had a normal auditory level, considered a hearing level, which is equal or better than 20 dB HL for all frequencies. The main changes were found to be a deterioration in the high frequency range (> 2 kHz) and a flat neurosensorial hearing loss, Table 3.

Table 3. Pure Tone Audiometry - Audiometric pattern

Normal	58 %
Flat Neurosensorial H. L.	10 %
High Frequency H. L.	21 %
Miscellaneous	11 %

Vocal Audiometry - We routinely search for the Speech Reception Threshold (S.R.T.) and the Speech Discrimination Threshold (S.D.T.) Score 30 dB over the S.R.T. The results are shown in Table 4.

Table 4. Results of Vocal Audiometry

S.R.T. - S.D.T.	
< 20 dB HL	46 %
20 - 40 dB HL	30 %
40 - 60 dB HL	4 %
> 60 dB HL	20 %
Discrimination Score	
> 80 %	80 %
< 80 % - > 60 %	5 %
< 60 %	15 %

Brain Evoked Response Audiometry (B.E.R.A.)- The mean and standard deviation of the wave latencies and InterPeakLatencies in the B.E.R.A. are shown in Table 5.

Table 5. B.E.R.A. - Values for the mean and standard deviation of the wave latencies and I.P.L.

Waves (Norm. Values)	**I** (1.4-1.8)	**III** (3.6-4.1)	**V** (5.5-6.0)	**I-III** (2.0-2.6)	**III-V** (1.8-2.5)	**I-V** (3.8-4.4)
Mean (ms)	1.53	3.63	5.70	2.12	2.43	3.71
StD	0.10	0.16	0.47	0.12	0.89	0.88

Basically, we found these values to be normal. However, considering the morphology of the graphic elements and particularly the InterPeakRatio (I.P.R.) between the amplitude of waves I and V, we found 35% of abnormalities in our cases.

EQUILIBRIOMETRIC EVALUATIONS

Cranio-Corpo-Graphy (C.C.G.) - We routinely perform the C.C.G. with the standing and the stepping test, according to Claussen's technique,[1,3,4,6] as described above. The standing test (Romberg test) showed two cases of discrete to moderate ataxia, all the others being normal. For the evaluation of the stepping test (Unterberger-Fukuda test) we use mainly two parameters, as follows; the lateral sway - which is the lateral displacement of the shoulders and the head between steps, and is measured in centimeters; and, the angular deviation - which is the angle between the initial and final position of the patient and is measured in degrees. The lateral sway is assumed to be related with central disorders and the angular deviation with peripheral lesions. With these two parameters we define, basically, four types of C.C.G, all of which are assumed to be related with a specific site of lesion and providing a very important clue for the topographic diagnosis. These four types are as follows: Type 1 - Normal; Type 2 - Peripheral lesion (there is an enhanced angular deviation with normal lateral sway): Type 3 - Central lesion (there is an enhanced lateral sway and the angular deviation is normal); and Type 4 - Combined, central plus peripheral lesion (there is an enhancement of the lateral deviation and the lateral sway). This test was normal in 55% of cases. The angular deviation was pathologically enhanced in 34% of cases, thus defining a Type 2 pattern of C.C.G. The lateral sway was the only disturbed parameter in 10% of the cases, depicting for a central -Type 3 - pattern of C.C.G.

Table 6. Cranio-Corpo-Graphy - results

Standing Test	
Normal	95 %
Ataxia	5 %
Stepping Test	
Type 1 (Normal)	55 %
Type 2 (Peripheral)	35 %
Type 3 (Central)	10 %

All patients with an equilibrium disturbance had an abnormal C.C.G.

Electronystagmography (E.N.G.) - As already stated, after calibrating the eye movements, we perform the E.N.G. looking for spontaneous nystagmus, fixation nystagmus and abnormalities in the smooth pursuit test. The results are shown in Table 7.

Table 7. Percentages of abnormalities in E.N.G.

	Normal	**Abnormal**
Spontan. Nystagmus	91 %	9 %
Fixation Nystagmus	100 %	0 %
Smooth Pursuit	95 %	5 %

Caloric Tests - For statistical purposes the caloric response is quantified by using the central frequency of the nystagmus - defined as the number of nystagmus beats during the period of 30 seconds of maximal response. The data are registered using the Claussen's butterfly.[3,4] The values for the mean and standard deviation of the central frequency of the nystagmus in the caloric tests are shown in Table 8.

Table 8. E.N.G. - Caloric test: Central frequency of nystagmus, for each stimulation
R - right **L** - left

(Normal Values)	**R 45** (25-57)	**R 27** (27-62)	**L 45** (26-60)	**L 27** (28-65)
Mean	39	25	33	25
StD	28	22	23	21

We found that only 30% of the calorizations were completely normal. All the others had at least one abnormal response. According to our interpretation, we classified the pathological calorizations as a peripheral disorder in 14 cases, that is ± 30% of the responses and 17 cases

of central lesions (±38%). We found a pathological unilateral weakness in 30% of the cases, and a pathological directional preponderance in 14% of cases.

Considering the two subgroups A and B representing the existence or absence of vestibular symptoms, the results are shown in Table 9.

Table 9. E.N.G. - Caloric tests

	E.N.G. - Caloric Tests	
	Group A (with vertigo)	**Group B** (no vertigo)
Normal	22 %	9 %
Abnormal	TOTAL - 78 % Desinhibited - 22 % Inhibited - 55 % Unilateral Weakness - 33 % Directional Prepond. - 11%	TOTAL - 90 % Desinhibited - 9 % Inhibited - 81 % Unilateral Weakness - 36 % Directional Prepond. - 18 %

Rotatory tests - The values for the mean and standard deviation of the number of nystagmus beats in the rotatory test are shown in Table 10.

Table 10. E.N.G. - Rotatory test results

	Rot. Right (28 - 63)	**Rot. Left** (28 - 62)
Mean	43	33
StD	24	26

Globally we had 12 normal responses, 16 inhibited and six desinhibited. Considering the classification into two subgroups, as for the other parameters, we found no significative differences between the group which related equilibrium disorders and the group with no symptoms of disequilibrium, as one can easily see in Table 11.

Table 11. E.N.G. - Rotatory test

	E.N.G. - Rotatory Test	
	Group A (with vertigo)	**Group B** (no vertigo)
Normal	33 %	38 %
Abnormal	TOTAL - 66 % Desinhibited- 22 % Inhibited - 44 % Directional Prepond. - 44 %	TOTAL - 62 % Desinhibited - 12 % Inhibited - 50 % Directional Prepond. - 25 %

DISCUSSION

1 - The most frequent symptom associated with tinnitus is hearing loss. In our sample, only 18% of the patients mentioned some equilibrium disturbance.

2 - The hearing loss is mainly neurosensorial, and characterised by a greater loss in the high frequency range (>2 kHz) and/or a flat loss. The supraliminal audiometry is, in our opinion, extremely important in the study of these patients. We routinely search for recruitment (S.I.S.I. and Metz tests) as a sign of cochlear lesion and for abnormal auditory adaptation (Tone decay and Reflex decay) as a sign of retrocochlear lesion, thus helping us with the topographic diagnosis. The results of these tests are not considered in this work. The vocal audiometry is also of a great value in the diagnosis of these patients. An unexpectedly low discrimination score is, in our experience, highly suspicious of a retrocochlear lesion, namely an acoustic neurinoma. In fact, we have in our sample, two cases of neurinomas that presented with tinnitus as the first and only symptom.

3 - Regarding the B.E.R.A., we can state that basically the wave latencies and InterPeakLatencies are normal except in two cases of acousticus neuroma. However, the graphic elements, namely the InterPeakRatio of the amplitude of the waves I/V, are abnormal in many cases (35%). These abnormalities in the graphic elements are very important and should always be looked for very carefully. The I.P.R. of the amplitude I/V is thought to be present in cases of central lesion, namely some lesions of the pons.[15]

4 - Although in our sample, 82% of the patients had no symptom related with their equilibrium, we found that only 55% of them had a normal C.C.G. In fact, one-third had an abnormally high angular deviation, indicating a peripheral lesion in the vestibular system, while another 10% had a C.C.G. pattern that suggests a lesion of central origin. These findings show that the vestibular system of tinnitus patients is not normal, even though they feel no equilibrium related symptom.

5 - The E.N.G. was completely normal in 30% of the patients. Therefore, the great majority of them (70%) had at least one abnormality in the vestibular testing. These abnormalities were classified as a peripheral lesion in 32% of cases and for a central lesion in 38%. We found no significant differences between the percentage of E.N.G. abnormalities when considering the subgroups of patients with and without vertigo. The most frequent pattern was an inhibited response. We also found some cases where in one ear we have a normal response with the warm stimulation and an inhibited response with the cold stimulation. We think, after Claussen, that this pattern is highly suggestive of an irritative state of the peripheral organ, as for instance, in endolymphatic

hydrops. So, we would like to emphasize the fact that, in our sample, while only 18% of the patients related an equilibrium problem, 66% of the patients had an abnormal vestibulometric evaluation.

CONCLUSIONS

Even though a small percentage of patients complain about disequilibrium (less than 20% in our study), many of them have abnormal vestibular responses (more or less 60%). Of these, roughly half of them have a peripheral pattern of lesion, and the others, a central pattern.
In our point of view, our data supports Shulman's concept that tinnitus might be the initial symptom of secondary endolymphatic hydrops (S.E.H.). If this proves to be true, we should expect these patients to progressively develop other symptoms of endolymphatic hydrops such as, sensorineural hearing loss and clinical vestibular dysfunction. Therefore, we think that these patients should be periodically re-evaluated in order to determine any development of the disease or diseases. Further studies are required before any specific conclusions can be made. We would like to emphasise the fact that we found abnormal vestibular tests in tinnitus patients with no vestibular complaints. This highlights the need for a complete neurootological evaluation of these patients.
In conclusion, we would like to strongly recommend that any tinnitus patient, whether or not he or she has any vestibular symptoms, to be completely evaluated, in terms of auditory and vestibular functions. Indeed, the cochleo-vestibular system must always be considered as a whole and studied as such.

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