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Tinnitus with or without hearing loss: are its characteristics different?

Marina Savastano

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Abstract The present study was carried out in order to analyze the clinical characteristics of tinnitus both in normal hearing subjects and in patients with hearing loss. The study considered 520 consecutive tinnitus sufferers. The following parameters were considered: age, sex, subjective disturbance caused by tinnitus, subjective judgment of tinnitus intensity, tinnitus laterality, tinnitus duration, tinnitus measurements, normal hearing or associated hearing loss. Among the patients considered, 223 have normal hearing while 297 have a hearing deficit. The hearing impairment was found to be in most cases of sensorineural type. The subjective discomfort is higher in presence of hearing loss. Subjects with hearing loss needed significantly higher masking levels. No evident differences in the residual inhibition (RI) result between the two groups were found. The present study confirms that tinnitus is most frequently associated with hearing loss. The characteristics of tinnitus in normal hearing subjects, except for the subjective judgment of tinnitus intensity, the pitch and the RI, are significantly different for those observed in subjects with hearing loss. The association of tinnitus and hearing deficit seems to increase the perceived severity of the symptom.

Keywords Tinnitus · Normal hearing · Hearing loss

Introduction

It is well documented in literature that tinnitus and hearing deficit are often related phenomena. Because hearing loss and tinnitus are so closely related, populations with more prevalent hearing loss have a correspondingly greater prevalence of tinnitus [13]. The percentage of subjects with tinnitus associated with hearing loss is very variable, according to the different results reported by various authors in literature, ranging between 85 and 96% of cases [1, 17, 19, 20, 26]. Up to the age of 16 the percentage of cases with tinnitus is 23.6–64% in children with hearing loss, even if for 17% of these cases there is a resolution of the tinnitus [3, 14, 30]. On the basis of epidemiologic studies on adults, the presence of tinnitus progressively increases with increasing age, and this is not so much correlated to senescence itself as to the frequent concomitant hearing loss. This occurs between the ages of 17 and 80, with an average of 49.52 among males and 50.95 among females [2, 4]. About 30% of all individuals between the ages of 65 and 74 and 50% of those who are 75 or older have hearing loss [5]. Although tinnitus is commonly associated with hearing loss, other medical factors become increasingly prevalent and must be considered as potential causes of tinnitus. These factors include conditions such as vascular disease, middle-ear disease, diabetes, hypertension, autoimmune disorders, and degenerative neural disorders, with or without concomitant hearing loss [22]. Furthermore, these medical conditions are accompanied by increasing use of medications, which may also cause tinnitus emergence or exacerbation [12]. The International Work Group on Hearing Problems and the Elderly [24] concluded that the incidence of tinnitus was not greater than that expected for older patients with hearing loss and other age-related diseases; in addition, the pathophysiology of tinnitus in older patients was the same as that in younger patients. Others have argued that age-related tinnitus exists as a distinct pathology and is related to degeneration at all levels of the auditory system [16]. For the aged population,

M. Savastano (✉)
Department of Medical–Surgical Specialities,
ENT Section, University of Padova, Via Giustiniani 2,
35128 Padova, Italy
e-mail: marina.savastano@unipd.it

tinnitus may go unreported or may be given less importance in the context of other significant medical problems.

Even if tinnitus is often associated with hearing deficit, tinnitus cases with normal hearing constitute an important group, but the studies performed up to now on this topic are restricted to hearing tests (otoacoustic emissions, ABR, high-frequency audiometry) without considering the tinnitus characteristics [6, 8, 28]. A broad consensus within the neuroscience of tinnitus holds that this audiologic condition is triggered by central deafferentation, mostly due to choclear damage. The absence of audiometrically detectable hearing loss however poses a challenge to this rather generalizing assumption. The results obtained recently by Weisz argue for the presence of a deafferentation also in tinnitus subjects with audiometrically normal thresholds and therefore favour the deafferentation assumption posed by most neuroscientific theories [34]. The isolated presence of tinnitus suggests that it may be a primitive sign of diseases that are only diagnosed after the onset of hearing loss. Riga et al. [23] suggest that patients with normal hearing acuity who have acute tinnitus seem to have a less effective functioning of the choclea efferent system.

Although tinnitus still remains one of the most challenging topic in clinical practice, there are only few reports about its characteristics, particularly related to the hearing function, assessed often using questionnaires. A direct collection of the characteristics of tinnitus data from a large population of tinnitus patients has been recently performed by Savastano [29], without specifying the different clinical features of tinnitus between normal and non-normal hearing subjects.

The present study was carried out in a large number of patients asking for a specialist examination exclusively for the symptom "tinnitus", in order to analyze the clinical characteristics of tinnitus both in normal hearing subjects and in patients with hearing loss. Moreover the purpose of the present analysis was to compare the tinnitus features observed in the two conditions, normal hearing and hearing loss.

Materials and methods

The study considered 520 consecutive tinnitus sufferers observed by the ENT Section of the Department of Medical-Surgical Specialities of Padova University. In the study, were included all tinnitus sufferers who sought help from an ENT Specialist only for this symptom. All patients with major health diseases and coexisting psychiatric disorders were excluded. The patients underwent previous therapies, when performed, on the basis of the related pathology: antibiotics, vasoactive, antioxidant drugs.

As for the analysis of data collected, the following parameters were considered: age, sex, subjective disturbance caused by tinnitus, subjective judgment of tinnitus intensity (low, medium, high), tinnitus laterality (unilateral or bilateral), tinnitus duration (recent: <1 year; mean: 1–5 years; old >5 years), tinnitus measurements, normal hearing or associated hearing loss. As for age, patients were divided into six groups: from 0 to 20, 21 to 30, 31 to 40, 41 to 50, 51 to 60, 61 to 70 and >70 .

The subjective discomfort caused by tinnitus, was tested using a Visual Analogue Scale (VAS). On this scale, the patient indicates his own discomfort level ranging from 0 to 10 (0 = absence of tinnitus; 10 = tinnitus perceived as catastrophic). These levels are divided into three types of discomfort: 0–2: slight; 3–6: moderate; 7–10: elevated. Moreover tinnitus annoyance was studied using the Tinnitus Handicap Inventory THI (Newman e coll) which helps to identify the degree of problems that tinnitus may be causing. It grades five categories of tinnitus severity: 1, slight; 2, mild; 3, moderate; 4, severe; 5, catastrophic.

The audiometric evaluation was performed using liminar audiometry, tympanometry with stapedius reflex and auditory brain stem responses. Magnetic resonance imaging (MRI) when retrocochlear hearing loss was suspected was also performed. The sample was divided into two groups: Group1 ($G1$) = subjects with normal hearing; Group2 ($G2$) = subjects with hearing loss. Audiometric threshold was considered as the pure tone average for the frequencies 0.5–1–2–4–8 kHz and divided according to the Bureau International D'Audiophonologie as follows: normal hearing (<20 dB); light hearing loss (21–40 dB); moderate hearing loss (41–70 dB); severe hearing loss (71–90 dB); profound hearing loss (>90 dB). Audiometric results were grouped into three categories: conductive hearing loss; sensorineural hearing loss (high frequency; low frequency; flat curve); mixed loss. Sensorineural hearing loss was further divided into three groups: high-frequency hearing loss (in the frequency 3, 4, 8 kHz); low-frequency hearing loss (250–500 Hz); flat curve. The high-frequency hearing loss was calculated as a mean of the thresholds for the worse ear over three frequencies: 3, 4 and 8 kHz. The hearing deficit was considered as presbycusis for those patients who were older than 60 years and had a bilateral, symmetrical, high-frequency hearing loss, with no other possible cause of hearing loss.

Tinnitus measurements included: stimulus matched to tinnitus (pure tone, narrow band, white noise), tinnitus loudness, spectral composition, masking effectiveness and RI. The pitch of the tinnitus (high- or low-pitched) was determined by a matching procedure and the difference between the hearing threshold and the sensation level was considered tinnitus loudness. The masking was performed with a wide frequency band noise in the same ear affected by tinnitus; its value consists of the difference between the threshold level of the masking sound and the threshold

necessary to mask tinnitus completely. Masking levels were divided into 0–30, 31–60, >60 dB. Residual inhibition (RI) was measured presenting the masking signal for 1 minute and observing, once the stimulus was suspended, the period of time for which tinnitus was inhibited. Three classes of RI were considered: negative (tinnitus still present); partial (tinnitus still present but improved for less or more than 60 s); complete (tinnitus completely disappeared for less or more than 60 s).

For the statistical analysis the Student *t*-test was calculated. We considered $p < 0.05$ to be significant.

Results

Among the 520 patients considered, 223 (43%) have normal hearing while 297 (57%) have a hearing deficit.

As for sex, considering the total population, 218 (42%) are female and 302 (58%) are male. The group of normal hearing subjects comprised 128 male (58%) and 94 (42%) female. The group of patients with tinnitus and associated hearing loss comprised of 173 (58%) male and 125 (42%) female.

The patients are aged between 27 and 79 years. The distribution of the decades of age is indicated in Fig. 1. No patients younger than 27 or older than 79 were observed. In group 1 the mean age is 49.77; in group 2 the mean age is 60.22.

In 26% of cases, it was not possible to correlate the tinnitus with a known etiology or anatomical site. Tinnitus was associated with noise related condition in 18% of cases, head and neck trauma in 8% of cases, middle ear pathology in 12.4% of cases, endocochlear hearing loss in 32.6% of patients, retrocochlear pathology in 2% and possible temporomandibular joint syndrome and barotrauma in 1% of cases.

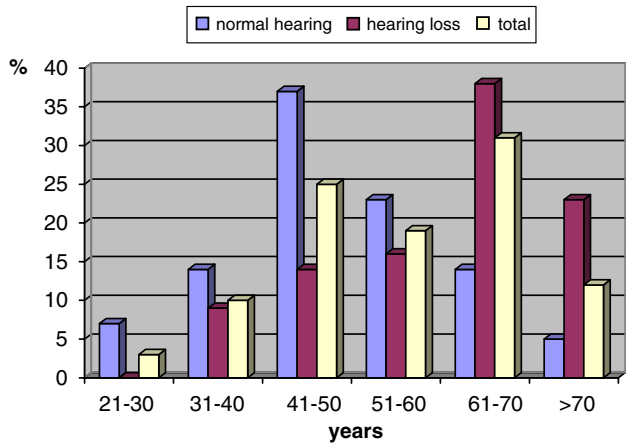

Fig. 1 Distribution of the decades of age for the total sample, the group of subjects with normal hearing and for the group with hearing loss

As for audiometric features observed in *G*2, 28 subjects (5.4%) had a conductive hearing loss, 445 subjects (85.6%) had a sensorineural hearing loss, 46 subjects (9%) had hearing loss of mixed type. In 65% of cases of sensorineural hearing loss the threshold shift was limited to high frequencies; in the 22 % to low frequencies; in 13 % to a flat loss. The mean threshold was 48.84 dB in the right ear and 46.7 dB in the left ear. The mean threshold for high-frequencies hearing loss was 41.2% dB.

Tinnitus was referred as unilateral in 54 % of cases (in the right ear in 56% of cases, in the left ear in 44% of cases), bilateral in 35% of cases, and in the head in the remaining cases. G1 tinnitus was referred as unilateral in 52 % of cases (in the right ear in 59% of cases, in the left ear in 41% of cases), bilateral in 38% of cases, and in the head in the remaining cases; *G*2 tinnitus was referred unilateral in 33% of cases (in the right ear in 40%, in the left ear in 60%), bilateral in 58% of cases and in the head in the remaining cases. As for tinnitus duration, it was present for >1 year in 49% of cases (48% in *G*1; 52% in *G*2), from 1 to 5 years in 32% of cases (55% in *G*1; 45% in *G*2) and >5 years in 19% of cases (38 % in *G*1; 62% in *G*2). In most cases, the patients reported their tinnitus as a pure tone (25% in *G*1 and 29% in *G*2); in relation to narrow-band (15 and 25%) and white noise (12 and 8%).

The level of the discomfort tested with the VAS was found in the entire sample between 0 and 2 in 1% of cases, 3 and 6 in 62% of cases, 7 and 10 in 37% of cases. Among subjects with normal hearing, the mean value of VAS was 4.5 ± 2.11; the level of disturbance was found between 0 and 2 in 1% of cases, 3 and 6 in 42% of cases, 7 and 10 in 5% of cases. Among subjects with hearing loss the mean value of VAS was 7.03 ± 1.58; the level of disturbance was found between 0 and 2 in 0% of cases, 3 and 6 in 20% of cases, 7 and 10 in 32% of cases. The distribution of annoyance degrees is reported in Fig. 2. The difference between the degrees reported by the two groups is statistically significant ($p = 0.020$). The correlation between the duration of tinnitus and annoyance degrees is not significant ($p = 0.06$). The data of THI (Fig. 3) show that in most cases a slight (17.2%) or mild (25.3%) grade was found for subjects with hearing loss, while the normal hearing subjects reported moderate (18.5%) and catastrophic (8.1%) grades in percentages statistically higher than the group of subjects with hearing loss ($p = 0.031$).

On the base of the subjective judgment, tinnitus intensity resulted low in 17% of cases, medium in 63% of cases and high in 20% of cases. In the two groups it was low respectively in the 22 and 13 of cases, medium in 55 and 69, high in 18 and 23% of cases. (Fig. 4) The mean value of the loudness was 21.66 ± 10.3 dB in the whole population, 14.98 ± 14.29 dB in the normal hearing group, 28.45 ± 15.91 dB in subjects with hearing loss. The statistical

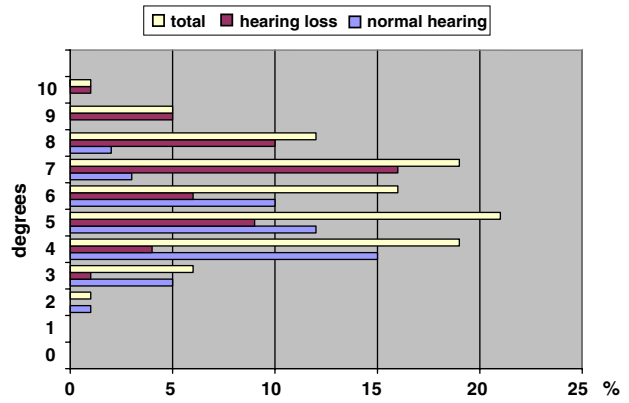

Fig. 2 Distribution of the degrees of discomfort evaluated with VAS

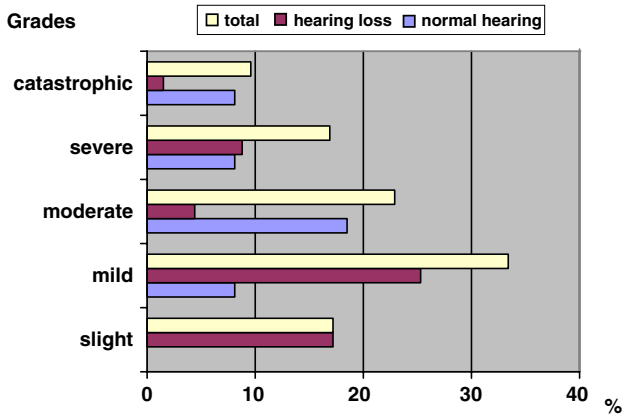

Fig. 3 Distribution of the grades of severity obtained with THI

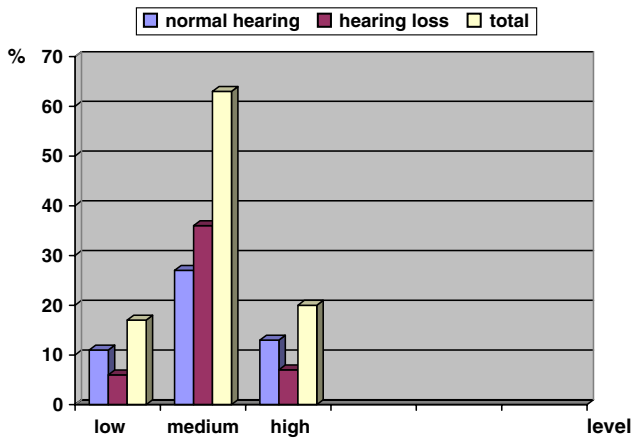

Fig. 4 Levels of tinnitus intensity referred by the patients

analysis showed a significant difference between the level of the loudness measured in the two groups ($p = 0.032$). The correlation between the duration of tinnitus and intensity level is not significant ($p = 0.07$).

The patients described their tinnitus as high-pitched in 75% of cases and low-pitched in 23% of cases. Only 2% of the subjects were unable to recognize their tinnitus in either of these categories. The mean frequency measured by the pitch-matching test resulted 4871 Hz for normal hearing subjects and 4113 Hz for patients with hearing loss. About 75% of the patients with high-pitched tinnitus had a high-frequency hearing loss ($p = 0.023$).

The mean masking level was 44.41 ± 18.65 dB in *G*1 and 58.32 ± 18.03 in *G*2. The distribution of the three categories of masking level is reported in Fig. 5. Statistical analysis showed a significant difference in the mean masking values between the two groups ($p = 0.024$).

Residual inhibition was negative in 280 subjects (53.8% of cases), 135 (48.3%) subjects of *G*1 and 145 (51.7%) of *G*2; partial in 164 subjects (31.5% of cases), 53 (32.3%) of *G*1 and 111 (67.7) of *G*2; total in 76 subjects (14.6%), 38 of *G*1 and 38 of *G*2 (Fig. 6). The mean time of RI in *G*1 was 12.5 ± 22.78 s and 16.18 ± 28.31 s in *G*2. The difference of the RI mean time between the two groups was not significant ($p = 0.06$).

Discussion

Among all subjects, there is a slight predominance of males (58% of males vs. 42% of females). There is also a prevalence of males both in the group of subjects with tinnitus and normal hearing (25% of males vs. 18% of females) and in the group of subjects with tinnitus and hearing loss (32% of males vs. 25% of females). One reason for this slight prevalence of men could be that they are generally exposed more than females to industrial noise and it is well known that chronic noise exposure is the main cause of tinnitus. The analysis of the epidemiological data indicates that exposure to noise is widespread and it is one of the most common causes of tinnitus, estimated at about 28% according to Axelsson, 20.7% according to Kowalska and 42% according to Palmer [1, 15, 21]. Among subjects who described their tinnitus as starting after excessive noise exposure Nicolas-Puel et al. [18] observed that they were mainly male and that there is a significant correlation between a history of exposure to noise trauma and the presence of a high-pitched tinnitus.

The decade of age in which the tinnitus was found most frequently is between 61 and 70 years followed by the decades 41–50, 51–60, 71–80, 31–40, 21–30 years. The increase in tinnitus prevalence in older patients does not necessarily mean that tinnitus as a separate and distinct symptom that will increase with age. Audiometric measurements of tinnitus correlate with hearing loss rather than with age. It is in fact interesting to observe that in the age range between 61 and 70 tinnitus is associated in most cases with hearing loss. In agreement with the findings by Sanchez et al. [25, 27], in the present study the mean age of the group of tinnitus sufferers with normal hearing is statistically younger than the group of subjects with tinnitus and

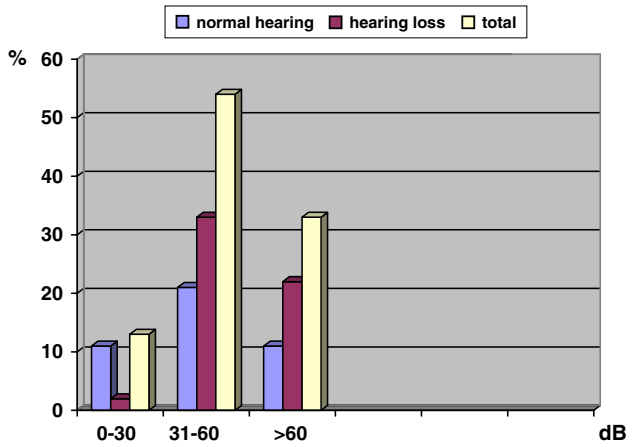

Fig. 5 Distribution of the masking levels

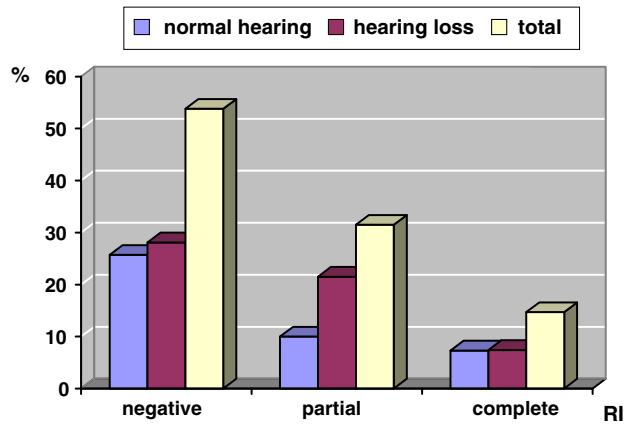

Fig. 6 Distribution of the kinds of residual inhibition

hearing loss. As it is well known, sensorineural hearing loss in elderly patients relatively often coexists with annoying tinnitus, termed presbytinnitus by Claussen [7]. As reported by Henry, Shulman and Zagòlski and et al., presbytinnitus like presbyacusis is due to pathologic alterations of the auditory pathways, both peripheral and central [12, 31, 35]. It appears between 45 and 55 years and reaches a peak around the age of 60; it is present in 24% of cases between 57 and 90 years of age [7, 32, 35]. Over 70 years the number of patients decreases because it seems, in agreement with the results by Henry, that the very aged population does not complain with tinnitus or gives it less importance in the context of other significant medical problems.

When present, the hearing impairment was found in most cases of sensorineural type, limited to the high frequencies and of light-moderate degree. Analogous results are shown by the study on 123 patients with tinnitus associated with hearing loss by Nicolas-Puel et al. who reported in most cases a high-frequency sensorineural hearing loss [4]. This finding was also referred by Satar and Hanry [11, 28]. In most cases tinnitus is high-pitched and there is a statistically significant association between high-pitched tinnitus and high-frequency hearing loss.

The subjective judgment of tinnitus intensity is of medium degree in over the half the cases, in analogous percentage in the two groups. This suggests that most patients seek for specialist examination when the symptom is already disturbing but before it becomes more severe. No significant correlation was found between the level of tinnitus intensity referred by patients and the hearing function. In most cases both groups reported a tinnitus of medium intensity and most of the patients who reported a high intensity tinnitus were normal hearing subjects. On the other hand the loudness measured by matching procedure correlates significantly with the presence and the degree of the threshold shift and seems to be the best predictor of perceived severity of the symptom as reported by Unterrainer et al. [33]. This datum disagrees with the finding by Nicolas-Puel, who reported a strong correlation between the degree of hearing loss and the self-perception of tinnitus loudness, but agrees with other studies in which the loudness match was found to be a function of the hearing threshold [9, 10, 18].

The subjective discomfort is higher in the presence of hearing loss than in a case of normal hearing. In fact among subjects with normal hearing the level of disturbance was moderate in most cases . Among subjects with hearing loss the level was slight only in 5% of cases, moderate in 12% of cases and elevated in 35% of cases. This could indicate that, in the majority of subjects, the presence of hearing loss increases the complaint of tinnitus considerably, even if the hearing deficit is not severe. Nevertheless, the results of the THI indicate that tinnitus, even if not accompanied by hearing impairment, may cause sleep disturbances and difficulty with any daily activity, more evident than those observed in patients with hearing loss. On the other hand, these data indicate that, when tinnitus is associated with hearing deficit, it can be heard only in a quiet environment and easily masked by environmental sound and easily forgotten with activities.

Most of the patients needed a tinnitus masking level ranging between 31 and 60 dB, but subjects with hearing loss needed masking levels significantly higher than those required for normal hearing patients. No evident differences were found in the RI results between the two groups. There was a negative or complete suppression of tinnitus in an analogous way both for normal and non-normal hearing subjects. In most cases RI was partial, anyway without significant differences in the inhibition duration between the two groups of subjects. This relief suggest that the depth and duration of tinnitus suppression is not necessarily linked with the hearing threshold. The results obtained by Roberts et al. (2006) suggest that the auditory pathway reorganization induced by hearing loss is not the principal source of the tinnitus sensation and provide, a necessary basis for optimizing RI in individual case.

Conclusions

Tinnitus is described as a symptom associated, in a high percentage of cases, with hearing loss but it can not rarely be present in subjects with normal hearing. The present study confirms that tinnitus is in most cases associated with hearing loss but in a percentage extremely lower than that referred till now in literature. Therefore it is possible to emphasize the importance of greater knowledge of the subjects with tinnitus and normal hearing. The characteristics of tinnitus in normal hearing subjects, except for the subjective judgment of tinnitus intensity, the pitch and the RI, are significantly different to those observed in subjects with hearing loss. Particularly significant is the greater level of loudness, maskability and subjective discomfort in the group of patients with hearing loss which seems to cause an increase in the perceived severity of the symptom.

We believe that this aspect of tinnitus is worthy of further investigations which we would like to continue to perform in our department.

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